Source: Editor of UTRA/FDD physical layer description

SMG2 UMTS Physical Layer Expert Group

UTRA Physical Layer Description
FDD parts
(v0.4, 1998-06-25)

This document describes the UTRA/FDD physical layer. This version v0.4 is based on v0.3.1, and is updated with the agreed changes at the Turin UMTS-L1 meeting, June 15-17.

1 UTRA physical layer – general description

1.1 Introduction

1.2 Definitions and abbreviations

ARQ	Automatic Repeat Request
BCCH	Broadcast Control Channel
BER	Bit Error Rate
BLER	Block Error Rate
BS	Base Station
CCPCH	Common Control Physical Channel
DCH	Dedicated Channel
DL	Downlink (Forward link)
DPCH	Dedicated Physical Channel
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
DS-CDMA	Direct-Sequence Code Division Multiple Access
FACH	Forward Access Channel
FDD	Frequency Division Duplex
FER	Frame Error Rate
Mcps	Mega Chip Per Second
MS	Mobile Station
ODMA	Opportunity Driven Multiple Access
OVSF	Orthogonal Variable Spreading Factor (codes)
PCH	Paging Channel
PG	Processing Gain
PRACH	Physical Random Access Channel
PUF	Power Up Function
RACH	Random Access Channel
RX	Receive
SCH	Synchronisation Channel
SF	Spreading Factor
SIR	Signal-to-Interference Ratio
TDD	Time Division Duplex
TFI	Transport-Format Indicator
TPC	Transmit Power Control
TX	Transmit
UL	Uplink (Reverse link)
VA	Voice Activity

1.3 Normative references

1.4 General description

1.4.1 FDD

1.4.2 TDD

2 Transport channels and physical channels (FDD)

2.1 General

2.2 Transport channels

Transport channels are the services offered by Layer 1 to the higher layers.

2.2.1 Dedicated transport channels

There exists only one type of dedicated transport channel, the Dedicated Channel (DCH).

2.2.1.1 DCH - Dedicated Channel

The Dedicated Channel (DCH) is a downlink or uplink transport channel that is used to carry user or control information between the network and a mobile station. The DCH thus corresponds to the three channels Dedicated Traffic Channel (DTCH), Stand-Alone Dedicated Control Channel (SDCCH), and Associated Control Channel (ACCH) defined within ITU-R M.1035. The DCH is transmitted over the entire cell or over only a part of the cell using lobe-forming antennas.

2.2.2 Common transport channels

There are four types of common transport channels: BCCH, FACH, PCH, and RACH.

2.2.2.1 BCCH - Broadcast Control Channel

The Broadcast Control Channel (BCCH) is a downlink transport channel that is used to broadcast system- and cell-specific information. The BCCH is always transmitted over the entire cell.

2.2.2.2 FACH - Forward Access Channel

The Forward Access Channel (FACH) is a downlink transport channel that is used to carry control information to a mobile station when the system knows the location cell of the mobile station. The FACH may also carry short user packets. The FACH is transmitted over the entire cell or over only a part of the cell using lobe-forming antennas.

2.2.2.3 PCH - Paging Channel

The Paging Channel (PCH) is a downlink transport channel that is used to carry control information to a mobile station when the system does not know the location cell of the mobile station. The PCH is always transmitted over the entire cell.

2.2.2.4 RACH - Random Access Channel

The Random Access Channel (RACH) is an uplink transport channel that is used to carry control information from a mobile station. The RACH may also carry short user packets. The RACH is always received from the entire cell.

2.3 Physical channels

2.3.1 The physical resource

The basic physical resource is the code/frequency plane. In addition, on the uplink, different information streams may be transmitted on the I and Q branch. Consequently, a physical channel corresponds to a specific carrier frequency, code, and, on the uplink, relative phase (0 or $\pi/2$).

2.3.2 Uplink physical channels

2.3.2.1 Dedicated uplink physical channels

There are two types of uplink dedicated physical channels, the uplink Dedicated Physical Data Channel (uplink DPDCH) and the uplink Dedicated Physical Control Channel (uplink DPCCH).

The uplink DPDCH is used to carry dedicated data generated at Layer 2 and above, i.e. the dedicated transport channel (DCH). There may be zero, one, or several uplink DPDCHs on each Layer 1 connection.

The uplink DPCCH is used to carry control information generated at Layer 1. The Layer 1 control information consists of known pilot bits to support channel estimation for coherent detection, transmit power-control (TPC) commands, and an optional transport-format indicator (TFI). The transport-format indicator informs the receiver about the instantaneous parameters of the different transport channels multiplexed on the uplink DPDCH, see further Section 3, and corresponds to the data transmitted in the same frame. There is one and only one uplink DPCCH on each Layer 1 connection.

Figure 1 shows the frame structure of the uplink dedicated physical channels. Each frame of length 10 ms is split into 16 slots, each of length T_{slot} = 0.625 ms, corresponding to one power-control period. A super frame corresponds to 72 consecutive frames, i.e. the super-frame length is 720 ms.

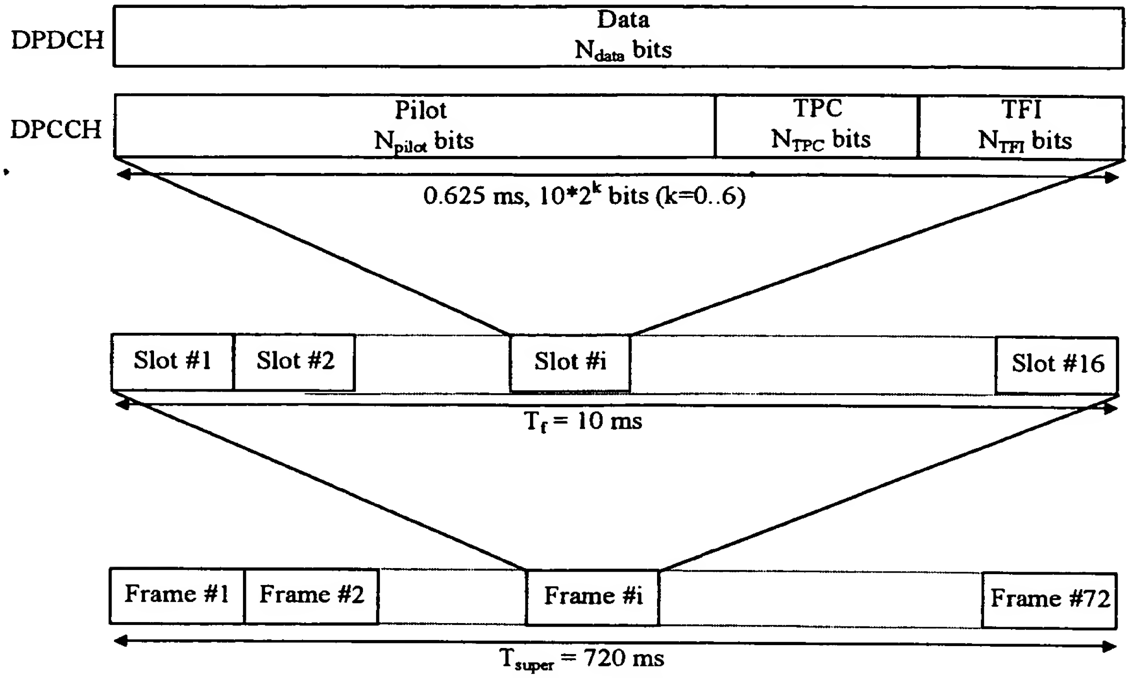


Figure 1. Frame structure for uplink DPDCH/DPCCH.

The parameter k in Figure 1 determines the number of bits per uplink DPDCH/DPCCH slot. It is related to the spreading factor SF of the physical channel as SF = $256/2^k$. The spreading factor may thus range from 256 down to 4. Note that an uplink DPDCH and uplink DPCCH on the same Layer 1 connection generally are of different rates, i.e. have different spreading factors and different values of k.

The exact number of bits of the different uplink DPCCH fields in Figure 1 (N_{pilot}, N_{TPC}, and N_{TFI}) is yet to be determined.

Multi-code operation is possible for the uplink dedicated physical channels. When multi-code transmission is used, several parallel DPDCH are transmitted using different channelization codes, see Section 4.2.2.1. However, there is only one DPCCH per connection.

2.3.2.2 Common uplink physical channels

2.3.2.2.1 Physical Random Access Channel

The Physical Random Access Channel (PRACH) is used to carry the RACH. It is based on a Slotted ALOHA approach, i.e. a mobile station can start the transmission of the PRACH at a number of well-defined time-offsets, relative to the frame boundary of the received BCCH of the current cell. The different time offsets are denoted *access slots* and are spaced 1.25 ms apart as illustrated in Figure 2. Information on what access slots are available in the current cell is broadcast on the BCCH.

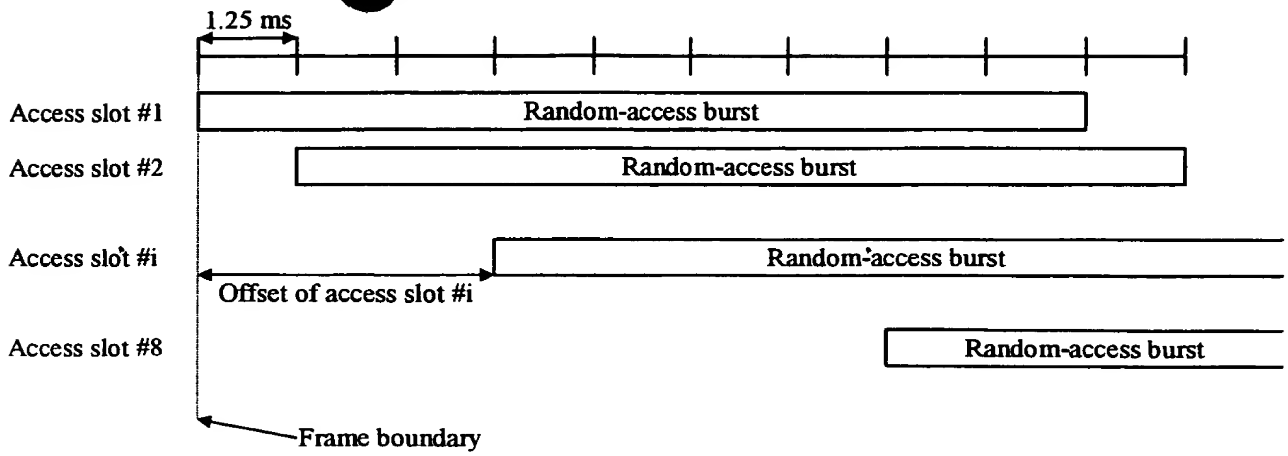


Figure 2. Access slots.

The structure of the random access burst of Figure 2, is shown in Figure 3. The random access burst consists of two parts, a *preamble* part of length 1 ms and a *message* part of length 10 ms. Between the preamble part and the message part there is an idle time period of length 0.25 ms (preliminary value). The idle time period allows for detection of the preamble part and subsequent on-line processing of the message part.

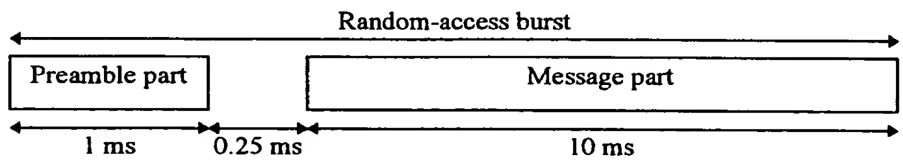


Figure 3. Structure of the Random Access burst.

Preamble part

The preamble part of the random-access burst consists of a *signature* of length 16 complex symbols (±1±j). Each preamble symbol is spread with a 256 chip real Orthogonal Gold code. There are a total of 16 different signatures, based on the Orthogonal Gold code set of length 16 (see Section 4.2.2.3.2 for more details).

Message part

The message part of the random-access burst has the same structure as the uplink dedicated physical channel. It consists of a data part, corresponding to the uplink DPDCH, and a Layer 1 control part, corresponding to the uplink DPCCH, see Figure 4. The data and control parts are transmitted in parallel. The data part carries the random access request or user packet. The spreading factor of the data part is limited to SF∈{256, 128, 64, 32} corresponding to channel bit rates of 16, 32, 64, and 128 kbps respectively. The control part carries pilot bits and rate information, using a spreading factor of 256. The rate information indicates which channelization code (or rather the spreading factor of the channelization code) is used on the data part, see further Section 4.2.2.3.

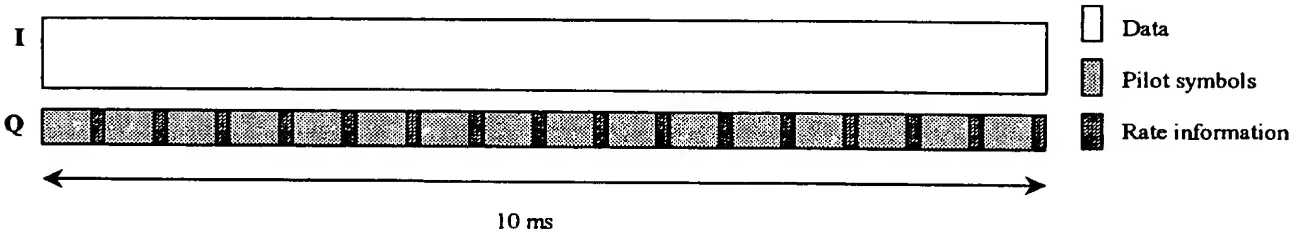


Figure 4. The message part of the random access burst.

Figure 5 shows the structure of the data part of the Random-Access burst. It consists of the following fields (the values in brackets are preliminary values):

- Mobile station identification (MS ID) [16 bits]. The MS ID is chosen at random by the mobile station at the time of each Random-Access attempt.

- Required Service [3 bits]. This field informs the base station what type of service is required (short packet transmission, dedicated-channel set-up, etc.)
- An optional user packet
- A CRC to detect errors in the data part of the Random-Access burst [8 bits].

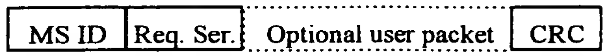


Figure 5. Structure of Random-Access burst data part.

< *Editor's note: This should be elaborated and maybe moved to another expert group.* >

2.3.3 Downlink physical channels

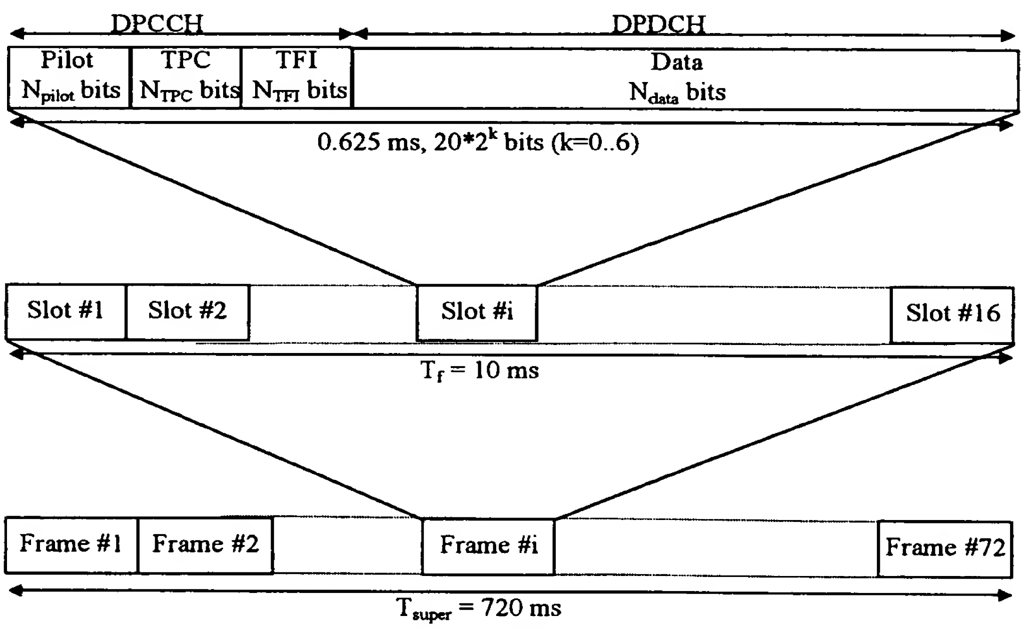
2.3.3.1 Dedicated physical channels

There is only one type of downlink dedicated physical channel, the Downlink Dedicated Physical Channel (downlink DPCH).

Within one downlink DPCH, dedicated data generated at Layer 2 and above, i.e. the dedicated transport channel (DCH), is transmitted in time-multiplex with control information generated at Layer 1 (known pilot bits, TPC commands, and an optional TFI). The downlink DPCH can thus be seen as a time multiplex of a downlink DPDCH and a downlink DPCCH, compare Section 2.3.2.1.

Figure 6 shows the frame structure of the downlink DPCH. Each frame of length 10 ms is split into 16 slots, each of length T_{slot} = 0.625 ms, corresponding to one power-control period. A super frame corresponds to 72 consecutive frames, i.e. the super-frame length is 720 ms.

Figure 6. Frame structure for downlink DPCH.



The parameter k in Figure 6 determines the total number of bits per downlink DPCH slot. It is related to the spreading factor SF of the physical channel as $SF = 256/2^k$. The spreading factor may thus range from 256 down to 4.

The exact number of bits of the different downlink DPCH fields in Figure 6 (N_{pilot}, N_{TPC}, N_{TFI}, and N_{data}) is yet to be determined.

Note that connection-dedicated pilot bits are transmitted also for the downlink in order to support the use of downlink adaptive antennas.

When the total bit rate to be transmitted on one downlink connection exceeds the maximum bit rate for a downlink physical channel, multicode transmission is employed, i.e. several parallel downlink DPCHs are transmitted for one connection using the same spreading factor. In this case, the Layer 1 control information is put on only the first downlink DPCH. The additional downlink DPCHs belonging to the connection do not transmit any data during the corresponding time period, see Figure 7.

Multiple codes may also transmitted in order to transmit different transport channels on different codes (code multiplex). In that case, the different parallel codes may have different spreading factors and the Layer 1 control information is transmitted on each code independently.

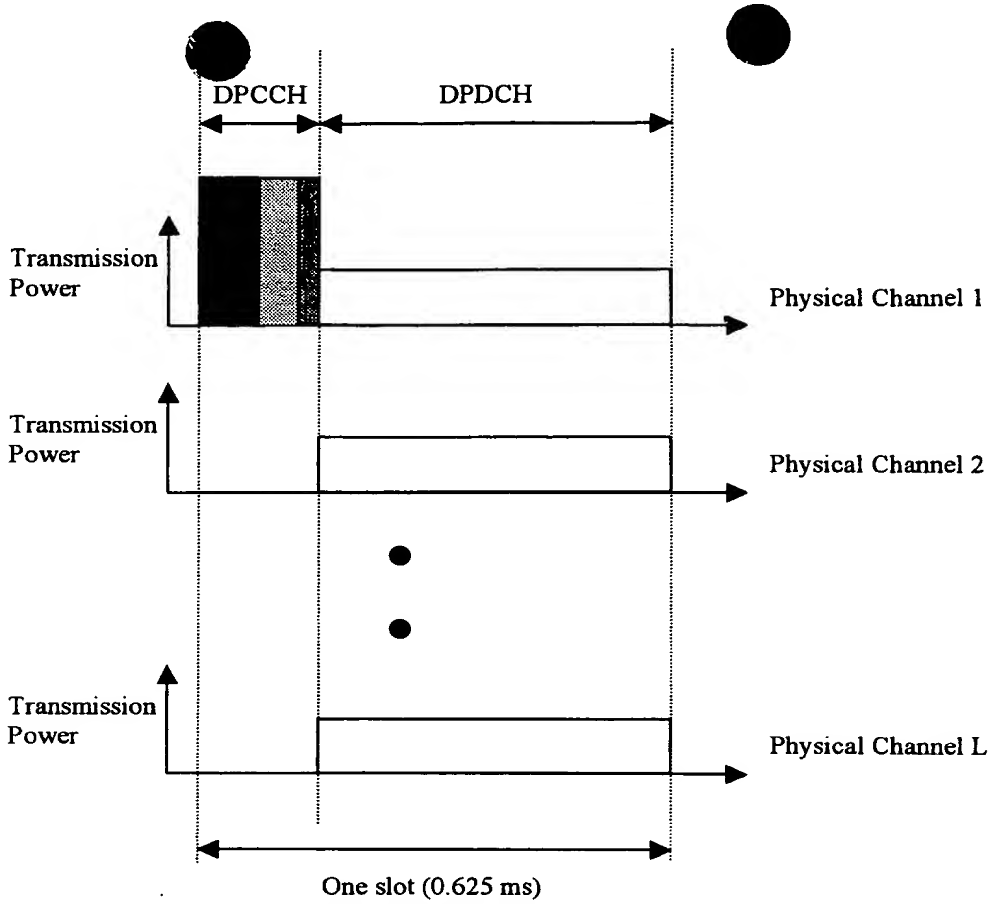


Figure 7. Downlink slot format in case of multi-code transmission.

2.3.3.2 Common physical channels

2.3.3.2.1 Primary Common Control Physical Channel (CCPCH)

The Primary CCPCH is a fixed rate (32 kbps, SF=256) downlink physical channels used to carry the BCCH. Figure 8 shows the frame structure of the Primary CCPCH. The frame structure differs from the downlink DPCH in that no TPC commands or TFI is transmitted. The only Layer 1 control information is the common pilot bits needed for coherent detection.

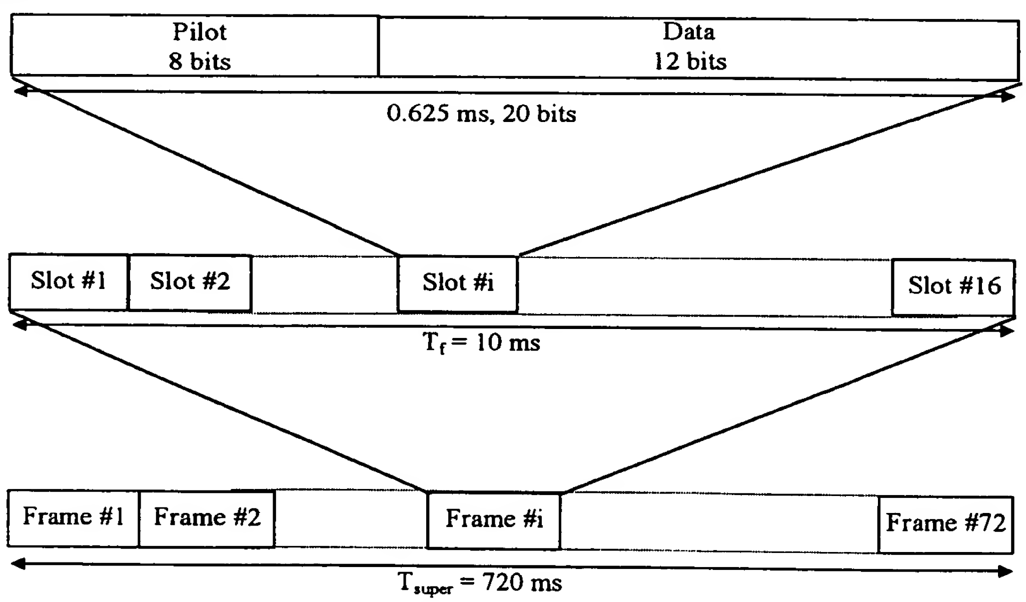


Figure 8. Frame structure for Primary Common Control Physical Channel.

2.3.3.2.2 Secondary Common Control Physical Channel

The secondary CCPCH is used to carry the FACH and PCH. It is of constant rate. However, in contrast to the Primary CCPCH, the rate may be different for different secondary CCPCH within one cell and between cells, in order to be able to allocate different amount of FACH and PCH capacity to a cell. The rate and spreading factor of each secondary CCPCH is broadcast on the BCCH. The set of possible rates is the same as for the downlink DPCH, see Section 2.3.3.1.

The frame structure of the Secondary CCPCH is shown in Figure 9.

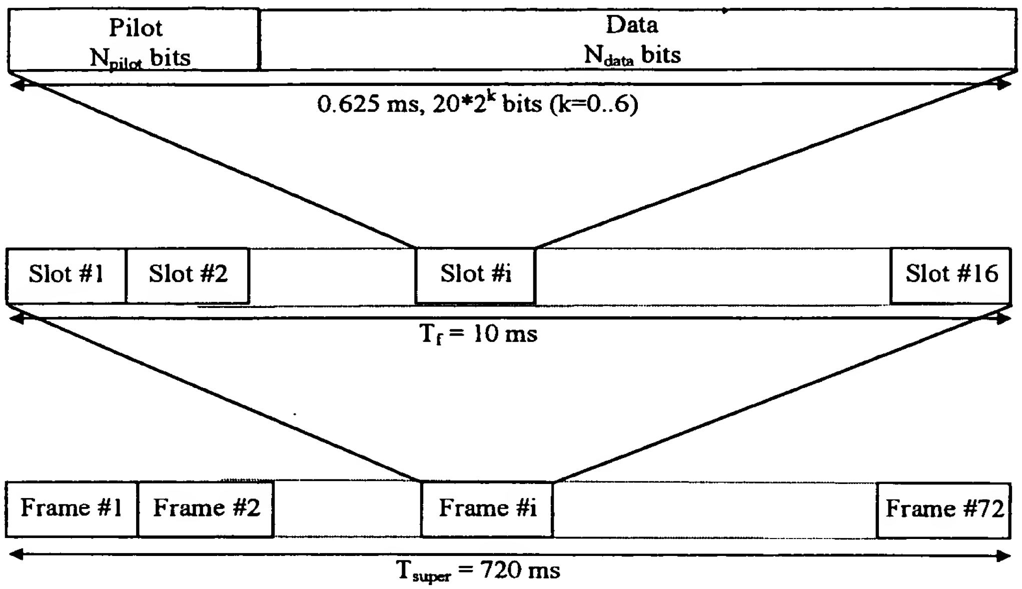
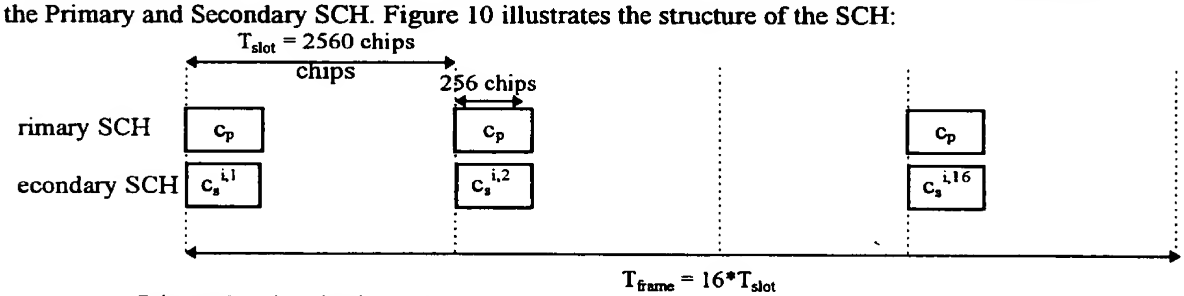


Figure 9. Frame structure for Secondary Common Control Physical Channel.

The FACH and PCH are mapped to separate Secondary CCPCHs. The main difference between a CCPCH and a downlink dedicated physical channel is that a CCPCH is not power controlled. The main difference between the Primary and Secondary CCPCH is that the Primary CCPCH has a fixed predefined rate while the Secondary CCPCH has a constant rate that may be different for different cells, depending on the capacity needed for FACH and PCH. Furthermore, a Primary CCPCH is continuously transmitted over the entire cell while a Secondary CCPCH is only transmitted when there is data available and may be transmitted in a narrow lobe in the same way as a dedicated physical channel (only valid for a Secondary CCPCH carrying the FACH).

2.3.3.2.3 Synchronisation Channel

The Synchronisation Channel (SCH) is a downlink signal used for cell search. The SCH consists of two sub channels, the Primary and Secondary SCH. Figure 10 illustrates the structure of the SCH:



c_p : Primary Synchronization Code

$c_s^{i,k}$: One of 17 possible Secondary Synchronization Codes

($c_s^{i,1}$, $c_s^{i,2}$, ..., $c_s^{i,16}$) encode cell specific long scrambling code group i

Figure 10. Structure of Synchronisation Channel (SCH).

The Primary SCH consists of an *unmodulated* orthogonal Gold code of length 256 chips, the Primary Synchronisation Code, transmitted once every slot. The Primary Synchronisation Code is the same for every base station in the system and is transmitted time-aligned with the BCCH slot boundary as illustrated in Figure 10.

The Secondary SCH consists of repeatedly transmitting a length 16 sequence of *unmodulated* Orthogonal Gold codes of length 256 chips, the Secondary Synchronisation Codes, transmitted in parallel with the Primary Synchronisation channel. Each Secondary Synchronisation code is chosen from a set of 17 different Orthogonal Gold codes of length

256. This sequence on the Secondary SCH indicates which of the 32 different code groups (see Section 4.3.2.2) the base station downlink scrambling code belongs. 32 sequences are used to encode the 32 different code groups each containing 16 scrambling codes. The 32 sequences are constructed such that their cyclic-shifts are unique, i.e., a non-zero cyclic shift less than 16 of any of the 32 sequences is not equivalent to some cyclic shift of any other of the 32 sequences. Also, a non-zero cyclic shift less than 16 of any of the sequences is not equivalent to itself with any other cyclic shift less than 16. This property is used to uniquely determine both the long code group and the frame timing in the second step of acquisition (see Section 6.3.1). The following sequences are used to encode the 32 different code groups each containing 16 scrambling codes (note that c_i indicates the i'th Secondary Short code of the 17 Orthogonal Gold codes).

$(c_1\ c_1\ c_2\ c_{11}\ c_6\ c_3\ c_{15}\ c_7\ c_8\ c_8\ c_7\ c_{15}\ c_3\ c_6\ c_{11}\ c_2)$
$(c_1\ c_2\ c_9\ c_3\ c_{10}\ c_{11}\ c_{13}\ c_{13}\ c_{11}\ c_{10}\ c_3\ c_9\ c_2\ c_1\ c_{16}\ c_{16})$
$(c_1\ c_3\ c_{16}\ c_{12}\ c_{14}\ c_2\ c_{11}\ c_2\ c_{14}\ c_{12}\ c_{16}\ c_3\ c_1\ c_{13}\ c_4\ c_{13})$
$(c_1\ c_4\ c_6\ c_4\ c_1\ c_{10}\ c_9\ c_8\ c_{17}\ c_{14}\ c_{12}\ c_{14}\ c_{17}\ c_8\ c_9\ c_{10})$
$(c_1\ c_5\ c_{13}\ c_{13}\ c_5\ c_1\ c_7\ c_{14}\ c_3\ c_{16}\ c_8\ c_8\ c_{16}\ c_3\ c_{14}\ c_7)$
$(c_1\ c_6\ c_3\ c_5\ c_9\ c_9\ c_5\ c_3\ c_6\ c_1\ c_4\ c_2\ c_{15}\ c_{15}\ c_2\ c_4)$
$(c_1\ c_7\ c_{10}\ c_{14}\ c_{13}\ c_{17}\ c_3\ c_9\ c_9\ c_3\ c_{17}\ c_{13}\ c_{14}\ c_{10}\ c_7\ c_1)$
$(c_1\ c_8\ c_{17}\ c_6\ c_{17}\ c_8\ c_1\ c_{15}\ c_{12}\ c_5\ c_{13}\ c_7\ c_{13}\ c_5\ c_{12}\ c_{15})$
$(c_1\ c_9\ c_7\ c_{15}\ c_4\ c_{16}\ c_{16}\ c_4\ c_{15}\ c_7\ c_9\ c_1\ c_{12}\ c_{17}\ c_{17}\ c_{12})$
$(c_1\ c_{10}\ c_{14}\ c_7\ c_8\ c_7\ c_{14}\ c_{10}\ c_1\ c_9\ c_5\ c_{12}\ c_{11}\ c_{12}\ c_5\ c_9)$
$(c_1\ c_{11}\ c_4\ c_{16}\ c_{12}\ c_{15}\ c_{12}\ c_{16}\ c_4\ c_{11}\ c_1\ c_6\ c_{10}\ c_7\ c_{10}\ c_6)$
$(c_1\ c_{12}\ c_{11}\ c_8\ c_{16}\ c_6\ c_{10}\ c_5\ c_7\ c_{13}\ c_{14}\ c_{17}\ c_9\ c_2\ c_{15}\ c_3)$
$(c_1\ c_{13}\ c_1\ c_{17}\ c_3\ c_{14}\ c_8\ c_{11}\ c_{10}\ c_{15}\ c_{10}\ c_{11}\ c_8\ c_{14}\ c_3\ c_{17})$
$(c_1\ c_{14}\ c_8\ c_9\ c_7\ c_5\ c_6\ c_{17}\ c_{13}\ c_{17}\ c_6\ c_5\ c_7\ c_9\ c_8\ c_{14})$
$(c_1\ c_{15}\ c_{15}\ c_1\ c_{11}\ c_{13}\ c_4\ c_6\ c_{16}\ c_2\ c_2\ c_{16}\ c_6\ c_4\ c_{13}\ c_{11})$
$(c_1\ c_{16}\ c_5\ c_{10}\ c_{15}\ c_4\ c_2\ c_{12}\ c_2\ c_4\ c_{15}\ c_{10}\ c_5\ c_{16}\ c_1\ c_8)$
$(c_1\ c_{17}\ c_{12}\ c_2\ c_2\ c_{12}\ c_{17}\ c_1\ c_5\ c_6\ c_{11}\ c_4\ c_4\ c_{11}\ c_6\ c_5)$
$(c_2\ c_8\ c_{11}\ c_{15}\ c_{14}\ c_1\ c_4\ c_{10}\ c_{10}\ c_4\ c_1\ c_{14}\ c_{15}\ c_{11}\ c_8\ c_2)$
$(c_2\ c_9\ c_1\ c_7\ c_1\ c_9\ c_2\ c_{16}\ c_{13}\ c_6\ c_{14}\ c_8\ c_{14}\ c_6\ c_{13}\ c_{16})$
$(c_2\ c_{10}\ c_8\ c_{16}\ c_5\ c_{17}\ c_{17}\ c_5\ c_{16}\ c_8\ c_{10}\ c_2\ c_{13}\ c_1\ c_1\ c_{13})$
$(c_2\ c_{11}\ c_{15}\ c_8\ c_9\ c_8\ c_{15}\ c_{11}\ c_2\ c_{10}\ c_6\ c_{13}\ c_{12}\ c_{13}\ c_6\ c_{10})$
$(c_2\ c_{12}\ c_5\ c_{17}\ c_{13}\ c_{16}\ c_{13}\ c_{17}\ c_5\ c_{12}\ c_2\ c_7\ c_{11}\ c_8\ c_{11}\ c_7)$
$(c_2\ c_{13}\ c_{12}\ c_9\ c_{17}\ c_7\ c_{11}\ c_6\ c_8\ c_{14}\ c_{15}\ c_1\ c_{10}\ c_3\ c_{16}\ c_4)$
$(c_2\ c_{14}\ c_2\ c_1\ c_4\ c_{15}\ c_9\ c_{12}\ c_{11}\ c_{16}\ c_{11}\ c_{12}\ c_9\ c_{15}\ c_4\ c_1)$
$(c_2\ c_{15}\ c_9\ c_{10}\ c_8\ c_6\ c_7\ c_1\ c_{14}\ c_1\ c_7\ c_6\ c_8\ c_{10}\ c_9\ c_{15})$
$(c_2\ c_{16}\ c_{16}\ c_2\ c_{12}\ c_{14}\ c_5\ c_7\ c_{17}\ c_3\ c_3\ c_{17}\ c_7\ c_5\ c_{14}\ c_{12})$
$(c_2\ c_{17}\ c_6\ c_{11}\ c_{16}\ c_5\ c_3\ c_{13}\ c_3\ c_5\ c_{16}\ c_{11}\ c_6\ c_{17}\ c_2\ c_9)$
$(c_2\ c_1\ c_{13}\ c_3\ c_3\ c_{13}\ c_1\ c_2\ c_6\ c_7\ c_{12}\ c_5\ c_5\ c_{12}\ c_7\ c_6)$
$(c_2\ c_2\ c_3\ c_{12}\ c_7\ c_4\ c_{16}\ c_8\ c_9\ c_9\ c_8\ c_{16}\ c_4\ c_7\ c_{12}\ c_3)$
$(c_2\ c_3\ c_{10}\ c_4\ c_{11}\ c_{12}\ c_{14}\ c_{14}\ c_{12}\ c_{11}\ c_4\ c_{10}\ c_3\ c_2\ c_{17}\ c_{17})$
$(c_2\ c_4\ c_{17}\ c_{13}\ c_{15}\ c_3\ c_{12}\ c_3\ c_{15}\ c_{13}\ c_{17}\ c_4\ c_2\ c_{14}\ c_5\ c_{14})$
$(c_2\ c_5\ c_7\ c_5\ c_2\ c_{11}\ c_{10}\ c_9\ c_1\ c_{15}\ c_{13}\ c_{15}\ c_1\ c_9\ c_{10}\ c_{11})$

The use of the SCH for cell search is described in detail in Section 6.3.

2.4 Mapping of Transport Channels to Physical Channels

Figure 11 summarises the mapping of transport channels to physical channels.

Transport Channels	Physical Channels
BCCH	Primary Common Control Physical Channel (Primary CCPCH)
FACH	Secondary Common Control Physical Channel (Secondary CCPCH)
PCH	
RACH	Physical Random Access Channel (PRACH)
DCH	Dedicated Physical Data Channel (DPDCH)
	Dedicated Physical Control Channel (DPCCH)
	Synchronisation Channel (SCH)

Figure 11. Transport-channel to physical-channel mapping.

The DCHs are coded and multiplexed as described in Section 3, and the resulting data stream is mapped sequentially (first-in-first-mapped) directly to the physical channel(s). The mapping of BCCH and FACH is equally straightforward, where the data stream after coding and interleaving is mapped sequentially to the Primary and

Secondary CCPCH respectively. Also for the RACH, the coded and interleaved bits are sequentially mapped to the physical channel, in this case the message part of the random access burst on the PRACH. The mapping of the PCH to the Secondary CCPCH is slightly more complicated to allow for an efficient sleep mode, and is described in the next section.

2.4.1 Method for mapping of PCH to Secondary CCPCH

The method used to map the PCH data to the Secondary CCPCH is shown in Figure 12.
The PCH is divided into several groups in one superframe, and layer 3 information is transmitted in each group. Each group of PCH shall have information amount worth of 4 slots, and consists of a total of 6 information parts: 2 Paging Indication (PI) parts - for indicating whether there are MS-terminated calls or not, and 4 Mobile User Identifier (MUI) parts - for indicating Identity of the paged mobile user.
In each group, PI parts are transmitted ahead of MUI parts.
In all groups, 6 information parts are allocated with a certain pattern in the range of 24 slots. By shifting each pattern by 4 slots, multiple 288 groups of PCH can be allocated on one Secondary Common Control Physical Channel.

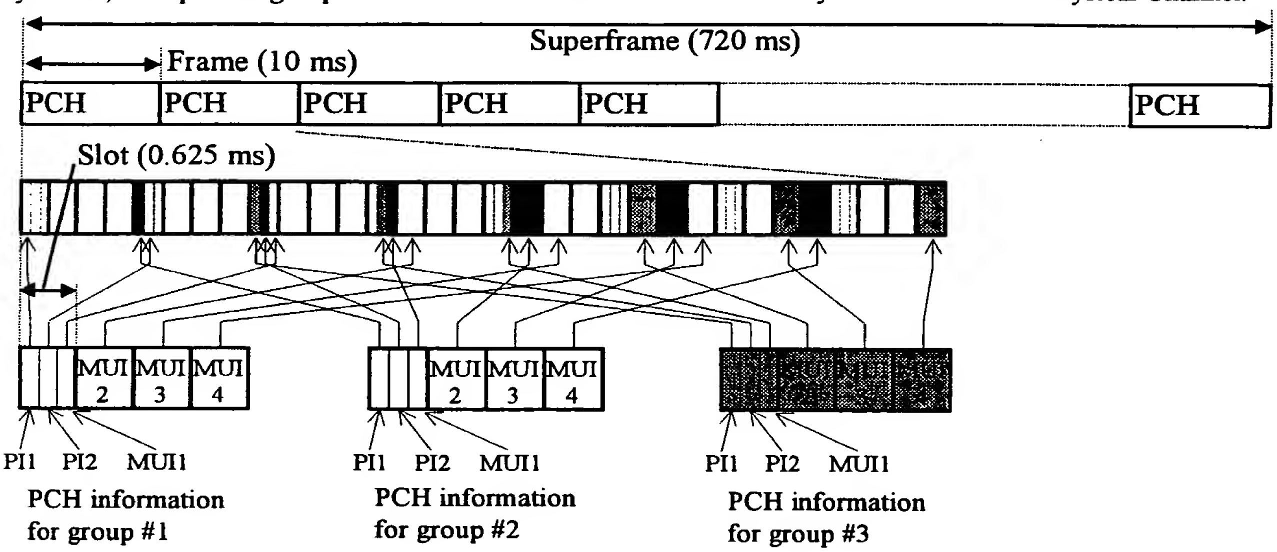


Figure 12. PCH mapping method.

2.5 Timing relationship between physical channels

In general, a BTS covers N cells, where $N \geq 1$. Each BTS has a Reference System Frame Number (SFN), which counts from 0 to $M-1$ in Radio Frame (10 ms) intervals. M is a multiple of the superframe (72), and is TBD. The purpose of the Reference SFN is to make sure that the correct frames are combined at soft handover. Each cell has a Cell SFN, which is broadcast on the BCCH.
Figure 13 shows the proposed physical channel timing parameters in a soft handover situation including two BTSs, BTS1 and BTS2. The timing parameters in Figure 13 refer to frame-timing.

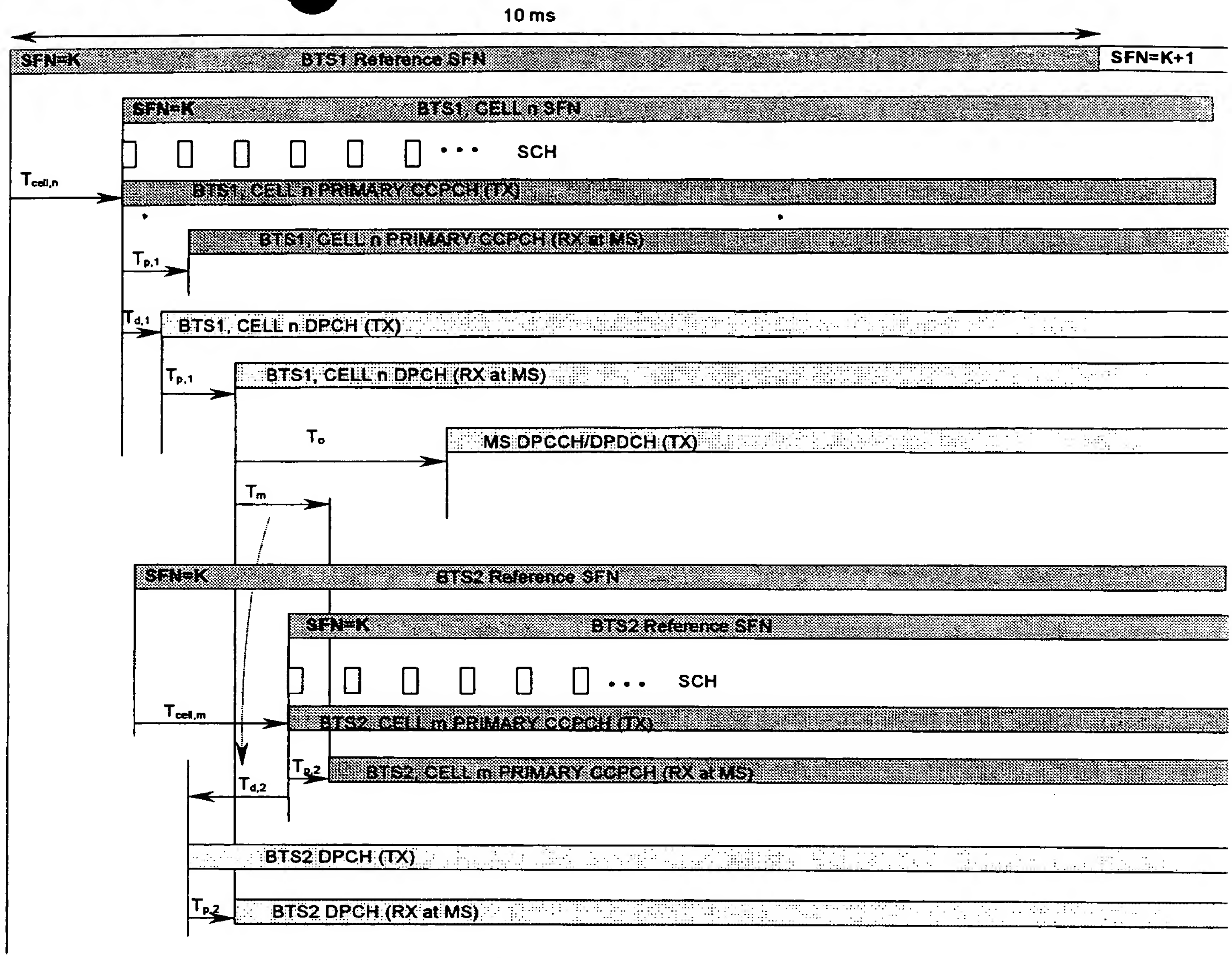


Figure 13. Physical channel timing relations

The parameters in Figure 13 are explained below:

- **T_p**: Propagation delay between BTS and MS.
- **T_{cell}**: This timing offset is used for the frame timing of SCH, Primary CCPCH and the starting phase of all downlink scrambling codes in a cell. The main purpose is to avoid having overlapping SCHs in different cells belonging to the same BTS. The resolution, which affects the number of possible sectors in a BTS, is TBD and depends on the maximum expected time-dispersion. The range is one slot. T_{cell} is also the reference frame timing for the PRACH.
- **T_d**: This timing offset is used for the frame timing of DPCHs and Secondary CCPCHs. It can be individually set up for each DPCH and Secondary CCPCH. The T_d values for the latter may be broadcast on the BCCH, or known a-priori. The purpose of T_d is:
  - In an originating/terminating cell, to distribute discontinuous transmission periods in time, and also to distribute BTS-RNC transmission traffic in time.
  - At soft handover, to synchronise downlink DPCHs to the same MS, in order to minimise the buffering requirements at the MS.

  The resolution is 256 chips in order to maintain downlink orthogonality and the range is TBD.
- **T_o**: This constant timing offset is used to set up the transmission frame timing of an uplink DPCCH/DPDCH in the MS. The uplink DPCCH/DPDCH transmission frame timing should be set to T_o seconds after the frame timing of the earliest received path of the downlink DPCH. T_o should be chosen to minimise the closed loop PC delay in as large cell-radii as possible. The value is TBD.

  The starting phase of the uplink scrambling code is synchronised with the uplink DPCCH/DPDCH frame timing.

- **T_m**: This value is measured by the MS and reported to the RNC prior to soft handover. The RNC can then notify this value to the target BTS, which then knows how to set T_d to achieve proper reception and transmission frame timing of the dedicated physical channel.

Note that since the MS reports the value T_m as the time-difference between the received Primary CCPCH frame-timing from the target BTS and the earliest received existing DPCH path, the propagation delay to the target BTS is already compensated for in the setting of T_d at the target BTS. The DPCH signal from the target BTS will reach the MS at the same time as the earliest received existing DPCH path. The only remaining error, besides frequency-drift and MS mobility related errors, is due to a (known) rounding error at the target BTS in order to maintain downlink orthogonality.

3 Multiplexing, channel coding and interleaving (FDD)

3.1 General

3.2 Transport-channel coding/multiplexing

Figure 14 illustrates the overall concept of transport-channel coding and multiplexing. The following steps can be identified:

- Channel coding, including optional transport-channel multiplexing
- Static rate matching
- Inter-frame interleaving
- Transport-channel multiplexing
- Dynamic rate matching
- Intra-frame interleaving

The different steps are described in detail below

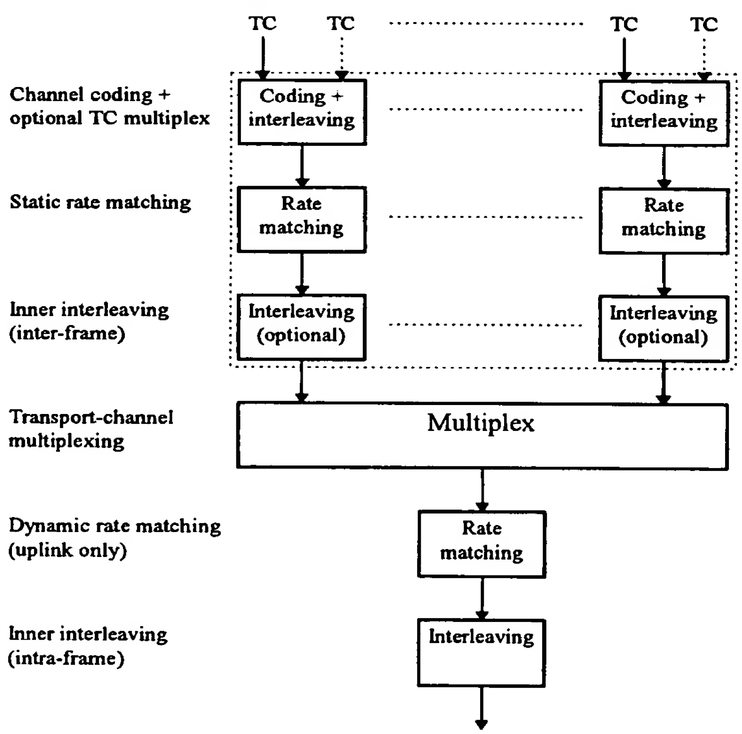


Figure 14. Coding and multiplexing of transport channels.

Note that although the coding, static rate matching, and inter-frame interleaving is done in parallel chains for different transport channels, some coordination in the parameter setting may be needed when adding, removing, or modifying transport channels (indicated by the dashed box in Figure 14).

The output after the inner interleaving is typically mapped to one DPDCH. Only for the very highest bit rates the output is split onto several DPDCHs, i.e. multi-code transmission.

Primarily, transport channels are coded and multiplexed as described above, i.e. into one data stream mapped on one or several physical channels. However, an alternative way of multiplexing services is to use code multiplexing, which corresponds to having several parallel multiplexing chains as in Figure 14, resulting in several data stream, each mapped to one or several physical channels.

3.2.1 Channel coding

Channel coding is done on a per-transport-channel basis, i.e. before transport-channel multiplexing.

The following options are available for the transport-channel specific coding, see also Figure 15:

- Convolutional coding
- Outer Reed-Solomon coding + Outer interleaving + Convolutional coding
- Turbo coding
- Service-specific coding, e.g. unequal error protection for some types of speech codecs.

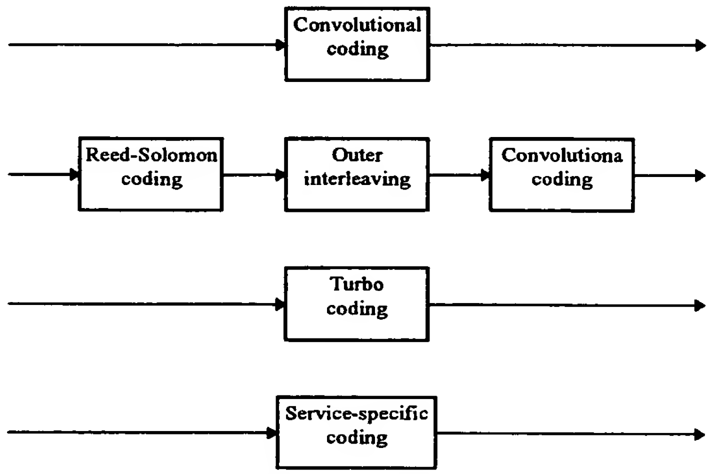


Figure 15. Channel coding in UTRA/FDD.

3.2.1.1 Convolutional coding

Convolutional coding is applied for services that require a BER in the order of 10^{-3}. Convolutional coding is also, in concatenation with RS coding + outer interleaving, applied to services that require a BER in the order of 10^{-6}, see also Section 3.2.1.2.

Table 1 lists the possible parameters for the convolutional coding

Rate	Constraint length	Generator polynomial 1	Generator polynomial 2	Generator polynomial 3
1/3	9	557	663	711
½	9	561	753	N/A

Table 1. Generator polynomials for the convolutional codes.

Typically, rate-1/3 convolutional coding is applied to dedicated transport channels (DCHs) in normal (non-slotted) mode while rate ½ convolutional coding is applied to DCHs in slotted mode, see Section 6.5.2.1.1.

3.2.1.2 Outer Reed-Solomon coding and outer interleaving

Reed-Solomon coding + outer interleaving, is, in concatenation with inner convolutional coding, typically applied to transport channels that require a BER in the order of 10^{-6}.

The RS-coding is of approximate rate 4/5 using the 256-ary alphabet.

The outer interleaving is symbol-based block interleaver with interleaver width equal to the block length of the RS code. The interleaver span is variable in the range 20 ms to 150 ms.

3.2.1.3 Turbo coding

The use of Turbo coding for high data rate (above 32 kbps), high quality services, is currently being investigated within ETSI. Turbo codes of rate 1/3 and ½ (for the highest data rates), have been proposed to replace the concatenation of convolutional and Reed-Solomon codes. ETSI is awaiting further results of simulations illustrating the performance of Turbo Codes.

The block diagram for the basic Turbo Encoder is shown in Figure 16.

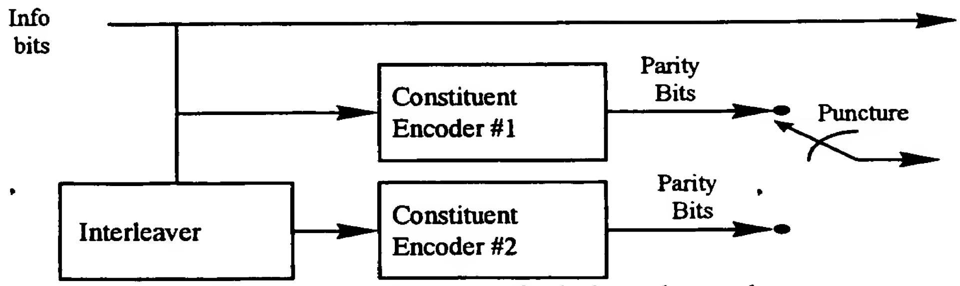


Figure 16. Block diagram of a Turbo code encoder.

3.2.1.4 Service specific coding

The service-specific-coding option allows for additional flexibility of the UTRA layer 1 by allowing for additional coding schemes, in addition to the standard coding schemes listed above. One example is the use of unequal-error-protection coding schemes for certain speech-codecs.

3.2.2 Inner inter-frame interleaving

Inner inter-frame bit interleaving is carried out on a per-transport-channel basis on those transport-channels that can allow for and require interleaving over more than one radio frame (10 ms). The span of the inner inter-frame interleaving can vary in the range 20 ms to 150 ms.

3.2.3 Rate matching

Two types of rate matching is carried out:

- Static rate matching carried out on a slow basis, typically every time a transport channel is added or removed from the connection.
- Dynamic rate matching carried out on a frame-by-frame (10 ms) basis

3.2.3.1 Static rate matching

Static rate matching is used for two different reasons:

- to adjust the coded transport channel bit rate to a level where minimum transmission quality requirements of each transport channel is fulfilled with the smallest differences in channel bit energy
- to adjust the coded transport channel bit rate so that the maximum total bit rate after transport channel multiplexing is matched to the channel bit rate of the uplink and downlink dedicated physical channel

The static rate matching is based on code puncturing and unequal repetition.

Note that, although static rate matching is carried out prior to transport-channel multiplexing, the rate matching must be co-ordinated between the different transport channels.

3.2.3.2 Dynamic rate matching

Dynamic rate matching is carried out after the multiplexing of the parallel coded transport channels and is used to match the total instantaneous rate of the multiplexed transport channels to the channel bit rate of the uplink DPDCH. Dynamic rate matching uses unequal repetition and is only applied to the uplink. On the downlink, discontinuous transmission (DTX) is used when the total instantaneous rate of the multiplexed transport channels does not match the channel bit rate.

3.2.3.3 Rate matching algorithm

Let's denote:

$S_N = \{N_1, N_2, \ldots, N_L\}$ = ordered set (in ascending order from left to right) of allowed number of bits per block

N_C = number of bits per matching block

$S_0 = \{d_1, d_2, \ldots, d_{N_C}\}$ = set of N_C data bits

P = maximum amount of puncturing allowed (tentatively 0.2, for further study)

The rate matching rule is as follows:

find N_i and N_{i+1} so that $N_i \le N_C < N_{i+1}$
j = 0

$$z = \left\lfloor \frac{N_{i+1}}{N_C} \right\rfloor$$

$if(z > 1 \& N_C \neq N_i)$

repeat every bit from set S_j z times

$N_C = N_C z$

$if(\frac{N_C - N_i}{N_C} < P)$

$x = N_C$

$y = N_C - N_i$

$S_j = \{d_1, d_2, \ldots, d_{N_C}\}$

do while $y > 1$

$z = \left\lceil \frac{x}{y} \right\rceil$, $k = \left\lfloor \frac{x}{z} \right\rfloor$

$x = x-k$

$y = y-k$

puncture every zth bit from set S_j

form new set S_{j+1} from not punctured bits of set S_j

$j = j+1$

end do

if y == 1

puncture last bit from set S_j

else

$x = N_C$

$y = N_{i+1} - N_C$

$S_j = \{d_1, d_2, \ldots, d_{N_C}\}$

do while $y > 1$

$z = \left\lceil \frac{x}{y} \right\rceil$, $k = \left\lfloor \frac{x}{z} \right\rfloor$

$x = x-k$

$y = y-k$

repeat every zth bit from set S_j

form new set S_{j+1} from not repeated bits of set S_j

$j = j+1$

end do

if y == 1

repeat first bit from set S_j

3.2.4 Transport-channel multiplexing

The coded transport channels are serially multiplexed within one radio frame. The output after the multiplexer (before the inner interleaving) will thus be according to Figure 17.

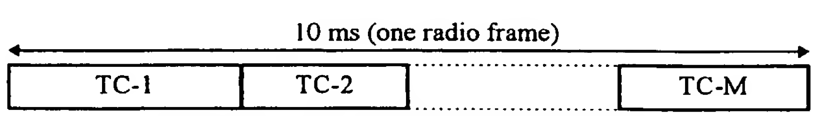


Figure 17. Transport channel multiplexing.

As an option, transport channels may be multiplexed within the channel-coding unit, typically after outer RS coding but before outer interleaving.

3.2.5 Inner intra-frame interleaving

Inner intra-frame interleaving over one radio frame (10 ms) is applied to the multiplexed set of transport channels.

3.3 Automatic Repeat Request (ARQ)

The details of the UTRA ARQ schemes are not yet specified. Therefore, the impact on layer 1, e.g. if soft combining of retransmitted packets is to take place, is not yet fully specified.

3.4 Coding for layer 1 control

3.4.1 Transport-format-indicator coding

The TFI bits are encoded using biorthogonal (32, 6) block code. The coding procedure is as shown in Figure 18.

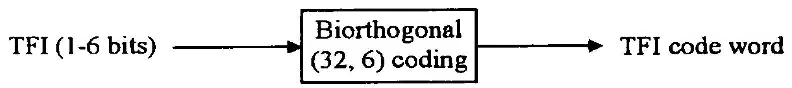


Figure 18. Channel coding of TFI bits.

If the TFI consist of less than 6 bits, it is padded with zeros to 6 bits, by setting the most significant bits to zero. The receiver can use the information that not all 6 bits are used for the TFI, thereby reducing the error rate in the TFI decoder. The length of the TFI code word is 32 bits. Thus there are 2 bits of (encoded) TFI in every slot of the radio frame. The code words of the biorthogonal block code are from the level 6 of the code three of OVSF codes defined in chapter 4.3.2.1. The code words, $C_6(i)$, $i = 0, \ldots, 31$, form an orthogonal set, $S_{C_6} = \{C_6(0), C_6(1), \ldots, C_6(31)\}$, of 32 code words of length 32 bits. By taking the binary complements of the code words of S_{C_6}, another set, $\bar{S}_{C_6} = \{\bar{C}_6(0), \bar{C}_6(1), \ldots, \bar{C}_6(31)\}$ is formed. These two sets are mutually biorthogonal yielding total of 64 different code words.

Mapping of the TFI bits to the code words is done as shown in the Figure 19.

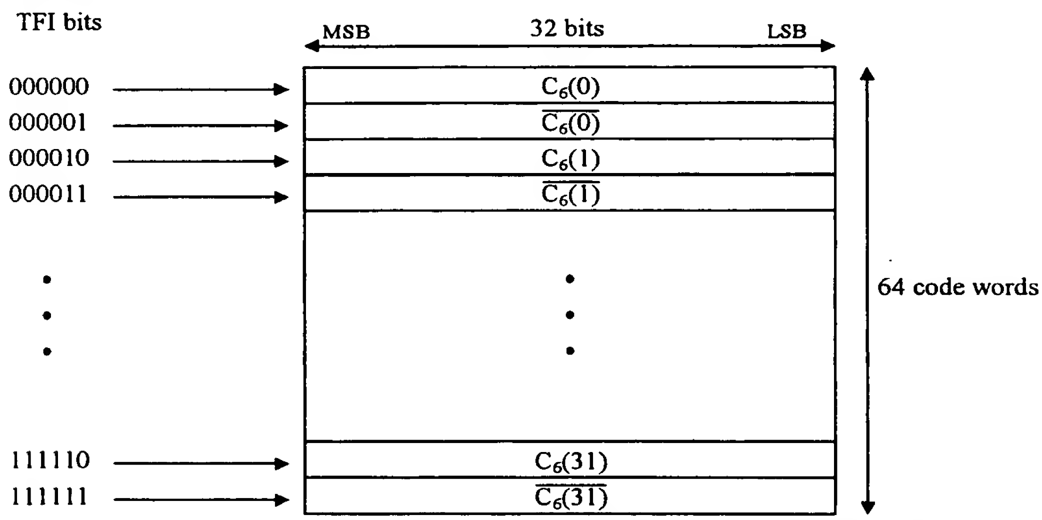


Figure 19. Mapping of TFI bits to biorthogonal code words.

Bits of the TFI code words are time multiplexed to the DPCCH as shown in the Figure 20. Within a slot the more significant bit is transmitted before the less significant bit.

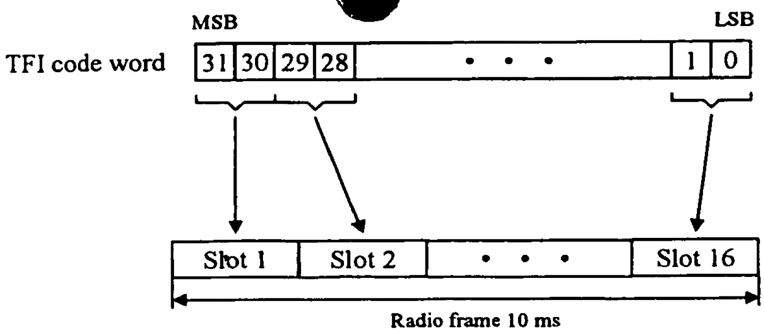


Figure 20. Time multiplexing of the bits of a TFI code word to radio frame.

4 Spreading and modulation (FDD)

4.1 General

4.2 Uplink spreading and modulation

4.2.1 Spreading

Uplink Dedicated Physical Channels (uplink DPDCH/DPCCH)

Figure 21 illustrates the spreading and modulation for the case of a single uplink DPDCH. Data modulation is dual-channel QPSK, where the uplink DPDCH and DPCCH are mapped to the I and Q branch respectively. The I and Q branch are then spread to the chip rate with two different channelization codes c_D/c_C and subsequently complex scrambled by a mobile-station specific complex scrambling code c_{scramb}

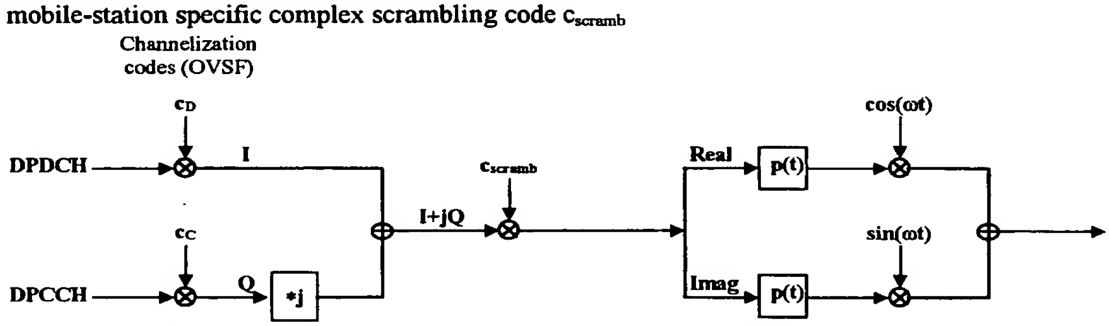


Figure 21. Spreading/modulation for uplink DPDCH/DPCCH.

For multi-code transmission, each additional uplink DPDCH may be transmitted on either the I or the Q branch. For each branch, each additional uplink DPDCH should be assigned its own channelization code. Uplink DPDCHs on different branches may share a common channelization code.

PRACH

The spreading and modulation of the message part of the Random-Access burst is basically the same as for the uplink dedicated physical channels, see Figure 21, where the uplink DPDCH and uplink DPCCH are replaced by the data part and the control part respectively. The scrambling code for the message part is chosen based on the base-station-specific preamble code, the randomly chosen preamble sequence, and the randomly chosen access slot (random-access time-offset), see Section 2.3.2.2.1. This guarantees that two simultaneous Random-Access attempts that use different preamble codes and/or different preamble sequences will not collide during the data part of the Random-Access bursts.

4.2.2 Code generation and allocation

4.2.2.1 Channelization codes

The channelization codes of Figure 21 are Orthogonal Variable Spreading Factor (OVSF) codes that preserves the orthogonality between a user's different physical channels. The OVSF codes can be defined using the code tree of Figure 22.

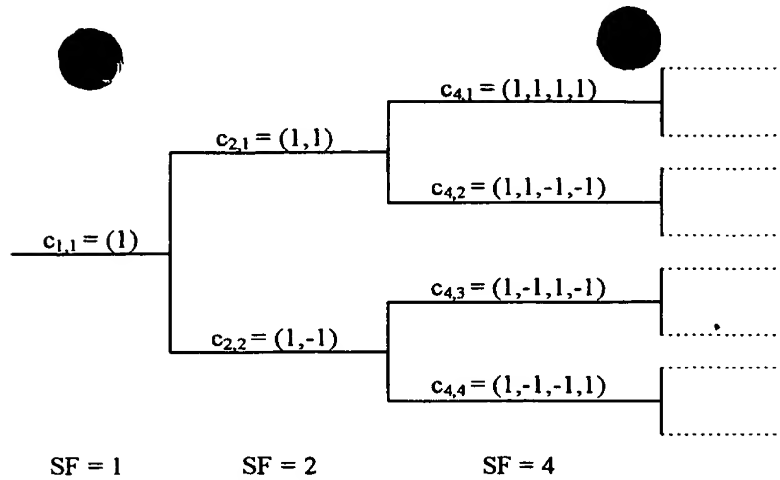


Figure 22. Code-tree for generation of Orthogonal Variable Spreading Factor (OVSF) codes.

Each level in the code tree defines channelization codes of length SF, corresponding to a spreading factor of SF in Figure 22. All codes within the code tree cannot be used simultaneously by one mobile station. A code can be used by a mobile station if and only if no other code on the path from the specific code to the root of the tree or in the sub-tree below the specific code is used by the same mobile station. This means that the number of available channelization codes is not fixed but depends on the rate and spreading factor of each physical channel.REFFORMATVERBINDEN

Each connection is allocated at least one uplink channelization code, to be used for the uplink DPCCH. In most cases, at least one additional uplink channelization code is allocated for a uplink DPDCH. Further uplink channelization codes may be allocated if more than one uplink DPDCH are required. All channelization codes used for the DPDCHs must be orthogonal to the code used for the DPCCH.

As different mobile stations use different uplink scrambling codes, the uplink channelization codes may be allocated with no co-ordination between different connections. The uplink channelization codes are therefore always allocated in a pre-defined order. The mobile-station and network only need to agree on the number and length (spreading factor) of the uplink channelization codes. The exact codes to be used are then implicitly given.

4.2.2.2 Scrambling codes

Either short or long scrambling codes should be used on uplink. The short scrambling code is typically used in cells where the base station is equipped with a an advanced receiver, such as a multi-user detector or interference canceller. With the short scrambling code the cross-correlation properties between different physical channels and users does not vary in time in the same way as when a long code is used. This means that the cross-correlation matrices used in the advanced receiver do not have to be updated as often as for the long scrambling codes case, thereby reducing the complexity of the receiver implementation. In cells where there is no gain in implementation complexity using the short scrambling code, the long code is used instead due to its better interference averaging properties.

4.2.2.2.1 Short scrambling code

The short scrambling code is a complex code $c'_{scramb} = c_I + jc_Q$, where c_I and c_Q are two different codes from the extended Very Large Kasami set of length 256.

The uplink short scrambling code is decided by the network. The mobile station is informed about what short scrambling code to use in the downlink Access Grant message that is the base-station response to an uplink Random Access Request.

The short scrambling code may, in rare cases, be changed during the duration of a connection.

4.2.2.2.2 Long scrambling code

The long uplink scrambling code is typically used in cells without multi-user detection in the base station. The mobile station is informed if a long scrambling code should be used in the Access Grant Message following a Random-Access request and in the handover message.

The scrambling code sequences are constructed as the position wise modulo 2 sum of 40960 chip segments of two binary *m*-sequences generated by means of two generator polynomials of degree 41. Let *x*, and *y* be the two *m*-sequences respectively. The *x* sequence is constructed using the primitive (over GF(2)) polynomial $1+X^3+X^{41}$. The *y* sequence is constructed using the polynomial $1+X^{20}+X^{41}$. The resulting sequences thus constitute segments of a set of Gold sequences.

The scrambling code for the quadrature component is a 1024-chip shifted version of the in-phase scrambling code.

The uplink scrambling code word has a period of one radio frame of 10 ms.

Let $n_{40} \ldots n_0$ be the binary representation of the scrambling code number n (decimal) with n_0 being the least significant bit. The x sequence depends on the chosen scrambling code number n and is denoted x_n, in the sequel. Furthermore, let $x_n(i)$ and $y(i)$ denote the i:th symbol of the sequence x_n and y, respectively

The m-sequences x_n and y are constructed as:

Initial conditions:

$x_n(0)=n_0,\ x_n(1)=n_1,\ \ldots =x_n(39)=n_{39},\ x_n(40)=n_{40}$

$y(0)=y(1)=\ldots =y(39)=y(40)=1$

Recursive definition of subsequent symbols:

$x_n(i+41)=x_n(i+3)+x_n(i)$ modulo 2, $i=0,\ldots,2^{41}-43$,

$y(i+41)=y(i+20)+y(i)$ modulo 2, $i=0,\ldots,2^{41}-43$.

The definition of the n:th scrambling code word for the in phase and quadrature components follows as (the left most index correspond to the chip scrambled first in each radio frame):

$C^I_{long,n} = < x_n(0)+y(0),\ x_n(1)+y(1),\ \ldots, x_n(40959)+y(40959) >$,

$C^Q_{long,n} = < x_n(1024)+y(1024),\ x_n(1025)+y(1025),\ \ldots,\ x_n(41983)+y(41983) >$,

again all sums being modulo 2 additions.

Now, the complex long scrambling code $C_{long,n}$ is defined by:

$$C_{long,n} = (C^I_{long,n} + jC^Q_{long,n}) = < ((x_n(0)+y(0)) + j(x_n(1024)+y(1024))),\ \ldots,\ ((x_n(40959)+y(40959)) + j(x_n(41983)+y(41983))) >$$

The code generator must be able to generate the sequence shifted arbitrarily from the initial state.

4.2.2.3 Random access codes

4.2.2.3.1 Preamble spreading code

The spreading code for the preamble part is cell specific and is broadcast by the base station. More than one preamble code can be used in a base station if the traffic load is high. The preamble codes must be code planned, since two neighbouring cells should not use the same preamble code.

The code used is a real-valued 256 chip Orthogonal Gold code. All 256 codes are used in the system. The preamble codes are generated in the same way as the codes used for the downlink synchronisation channel and are defined in Section 4.3.2.3.

4.2.2.3.2 Preamble signature

The preamble part carries one of 16 different orthogonal complex signatures of length 16, $<P_0, P_1, \ldots, P_{15}>$. The signatures are based on a set of Orthogonal Gold codes of length 16 and are specified in Table 2. The base station broadcasts which signatures are allowed to be used in a cell.

	Preamble symbols															
Signature	P_0	P_A	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}
1	A	A	A	-A	-A	-A	A	-A	-A	A	A	-A	A	-A	A	A
2	-A	A	-A	-A	A	A	A	-A	A	A	A	-A	-A	A	-A	A
3	A	-A	A	A	A	-A	A	A	-A	A	A	A	-A	A	-A	A
4	-A	A	-A	A	-A	-A	-A	-A	-A	A	-A	A	-A	A	A	A
5	A	-A	-A	-A	-A	A	A	-A	-A	-A	-A	A	-A	-A	-A	A
6	-A	-A	A	-A	A	-A	A	-A	A	-A	-A	A	A	A	A	A
7	-A	A	A	A	-A	-A	A	A	A	-A	-A	-A	-A	-A	-A	A
8	A	A	-A	-A	-A	-A	-A	A	A	-A	A	A	A	A	-A	A
9	A	-A	A	-A	-A	A	-A	A	A	A	-A	-A	-A	A	A	A
10	-A	A	A	-A	A	A	-A	A	-A	-A	A	A	-A	-A	A	A
11	A	A	A	A	A	A	-A	-A	A	A	-A	A	A	-A	-A	A
12	A	A	-A	A	A	A	A	A	-A	-A	-A	-A	A	A	A	A

13	A	-A	-A	-A	A	-A	-A	-A	A	-A	A	-A	-A	-A	A	A
14	-A	-A	-A	A	-A	A	A	A	A	A	A	A	A	-A	A	A
15	-A	-A	-A	-A	A	-A	-A	A	-A	A	-A	-A	A	-A	-A	A
16	-A	-A	A	A	-A	A	-A	-A	-A	-A	A	-A	A	A	-A	A

Table 2. Preamble signatures. $A = 1+j$.

4.2.2.3.3 Channelization codes for the message part

The signature in the preamble specifies one of the 16 nodes in the code-tree that corresponds to channelization codes of length 16, as shown in Figure 23. The sub-tree below the specified node is used for spreading of the message part. The control (Q-branch) is spread with the channelization code of spreading factor 256 in the lowest branch of the sub-tree. The data part (I-branch) can use any of the channelization codes from spreading factor 32 to 256 in the upper-most branch of the sub-tree. However, the system may restrict the set of codes (spreading factors) actually allowed in the cell, through the use of a BCCH message.

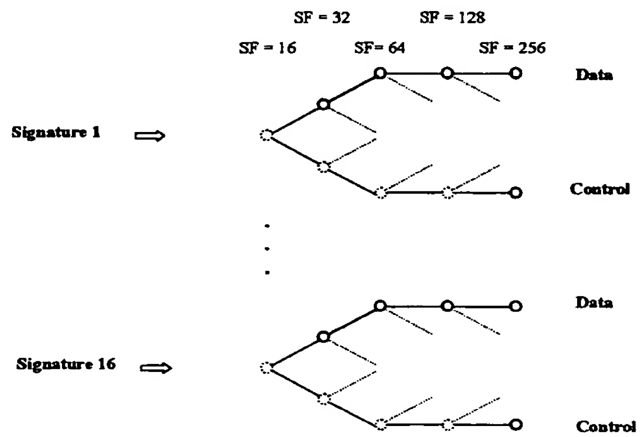


Figure 23. Channelization codes for the random access message part.

Since the control part is always spread with a known channelization code of length 256, it can be detected by the base station. The rate information field of the control part informs the base station about the spreading factor used on the data part. With knowledge of the sub-tree (obtained from the preamble signature) and the spreading factor (obtained from the rate information), the base station knows which channelization code is used for the data part.

This structure allows for simultaneous detection of multiple random access messages arriving in the same access slot, as long as different signatures are used.

4.2.2.3.4 Scrambling code for the message part

In addition to spreading, the message part is also subject to scrambling with a 10 ms complex code. The scrambling code is cell-specific and has a one-to-one correspondence to the spreading code used for the preamble part. Note that although the scrambling code is the same for every access slot, there is no scrambling-code collision problems between different access slots due to the 1.25 ms time shifts between the access slots.

The scrambling codes used are from the same set of codes as is used for the other dedicated uplink channels. The first 256 codes are used for the random access channel. The generation of these codes is explained in Section 4.3.2.2.

4.2.3 Modulation

4.2.3.1 Modulating chip rate

The modulating chip rate is 4.096 Mcps. This basic chip rate can be extended to 8.192 or 16.384 Mcps.

4.2.3.2 Pulse shaping

The pulse-shaping filters are root-raised cosine (RRC) with roll-off α=0.22 in the frequency domain.

4.2.3.3 Modulation

QPSK modulation is used.

4.3 Downlink spreading and modulation

4.3.1 Spreading

Figure 24 illustrates the spreading and modulation for the downlink DPCH and CCPCHs. Data modulation is QPSK where each pair of two bits are serial-to-parallel converted and mapped to the I and Q branch respectively. The I and Q branch are then spread to the chip rate with the same channelization code c_{ch} (real spreading) and subsequently scrambled by the same cell specific scrambling code c_{scramb} (real scrambling).

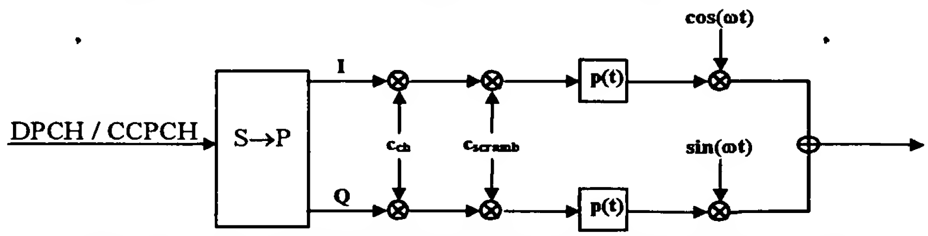


Figure 24. Spreading/modulation for downlink DPCH and CCPCHs.

The different physical channels use different channelization codes, while the scrambling code is the same for all physical channels in one cell.
The multiplexing of the SCH with the other downlink physical channels (DPCH and CCPCH) is illustrated in Figure 25. The figure illustrates that the SCH is only transmitted intermittently (one codeword per slot) and also that the SCH is multiplexed *after* long code scrambling of the DPCH and CCPCH. Consequently, the SCH is *non-orthogonal* to the other downlink physical channels.

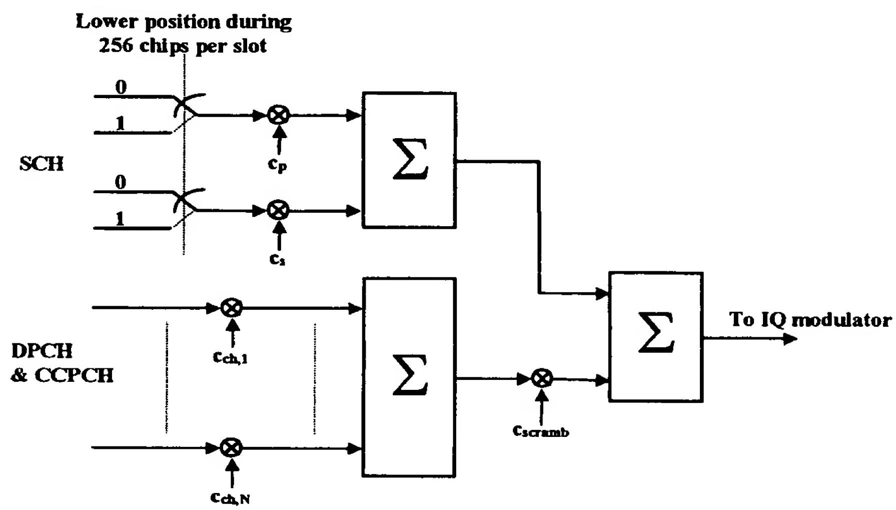


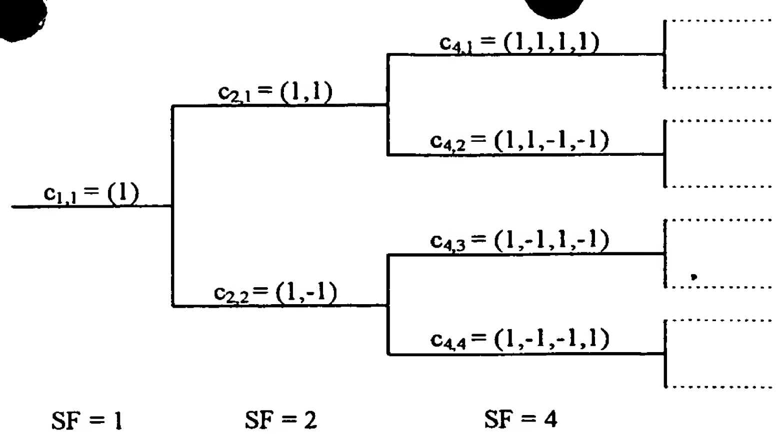
Figure 25. Multiplexing of SCH.

<Editor's note: The above two figures should be drawn in a more consistent way, maybe as one figure only. >

4.3.2 Code generation and allocation

4.3.2.1 Channelization codes

The channelization codes of Figure 24 are the same codes used in the uplink, namely Orthogonal Variable Spreading Factor (OVSF) codes that preserve the orthogonality between downlink channels of different rates and spreading factors. The OVSF codes are defined in Figure 22 in Section REFFORMATVERBINDEN



EINBETTEN
*SEQARABISCH*REFFORMATVERBINDENThe same restriction on code allocation applies as for the uplink, but for a cell and not a mobile station as in the uplink. Hence, in the downlink a code can be used in a cell if and only if no other code on the path from the specific code to the root of the tree or in the sub-tree below the specific code is used in the same cell.

The channelization code for the BCCH is a predefined code which is the same for all cells within the system.

The channelization code(s) used for the Secondary Common Control Physical Channel is broadcast on the BCCH.

The channelization codes for the downlink dedicated physical channels are decided by the network. The mobile station is informed about what downlink channelization codes to receive in the downlink Access Grant message that is the base-station response to an uplink Random Access request. The set of channelization codes may be changed during the duration of a connection, typically as a result of a change of service or an inter-cell handover. A change of downlink channelization codes is negotiated over a DCH.

4.3.2.2 Scrambling code

The total number of available scrambling codes is 512, divided into 32 code groups with 16 codes in each group. The grouping of the downlink codes is done in order to facilitate a fast cell search, see Section 6.3. The downlink scrambling code is assigned to the cell (sector) at the initial deployment. The mobile station learns about the downlink scrambling code during the cell search process, see Section 6.3.

In order to avoid code limitation in some cases, e.g. when increasing the capacity using adaptive antennas, the possibility to associate several scrambling codes with one cell (BCCH area) has been identified as one solution. The exact implementation of such a scheme is still to be determined.

The scrambling code sequences are constructed as the position wise modulo 2 sum of 40960 chip segments of two binary *m*-sequences generated by means of two generator polynomials of degree 18. Let *x*, and *y* be the two sequences respectively. The *x* sequence is constructed using the primitive (over GF(2)) polynomial $1+X^7+X^{18}$. The y sequence is constructed using the polynomial $1+X^5+X^7+X^{10}+X^{18}$. The resulting sequences thus constitute segments of a set of Gold sequences.

The scrambling codes are repeated for every 10 ms radio frame.

Let n_{17} ... n_0 be the binary representation of the scrambling code number n (decimal) with n_0 being the least significant bit. The x sequence depends on the chosen scrambling code number n and is denoted x_n, in the sequel. Furthermore, let $x_n(i)$ and $y(i)$ denote the i:th symbol of the sequence x_n and y, respectively

The *m*-sequences x_n and y are constructed as:

Initial conditions:

$x_n(0)=n_0,\ x_n(1)=n_1,\ \ldots\ =x_n(16)=n_{16},\ x_n(17)=n_{17}$

$y(0)=y(1)=\ \ldots\ =y(16)=y(17)=1$

Recursive definition of subsequent symbols:

$x_n(i+18)=x_n(i+7)+x_n(i)$ modulo 2, $i=0,\ldots,2^{18}-20$,

$y(i+18)=y(i+10)+y(i+7)+y(i+5)+y(i)$ modulo 2, $i=0,\ldots,2^{18}-20$.

All sums of symbols are taken modulo 2.

The definition of the *n*:th scrambling code word follows as (the left most index correspond to the chip scrambled first in each radio frame):

$C_{scramb,n} = < x_n(0)+y(0),\ x_n(1)+y(1),\ \ldots,x_n(40959)+y(40959) >$,

again all symbol sums being modulo 2 additions.

The index *n* runs from 0 to 511 giving 512 distinct 40960 chip segments of a corresponding Gold code sequence. The leftmost chip in $C_{scramb,n}$ corresponds to the first chip in a 10 ms radio frame and the rightmost to the last.

The sign of the I- and Q-branch component is changed if and only if the corresponding chip in $C_{scramb,n}$ equals '1'.

The code generator must be able to generate the sequence shifted arbitrarily from the initial state.

4.3.2.3 Synchronisation codes

The Primary and Secondary code words, C_p and $\{C_1,\ldots,C_{17}\}$ respectively, consist of pair wise mutually orthogonal Gold codes of length 256. The Primary SCH is furthermore chosen to have good aperiodic auto correlation properties. The code sequences are constructed with the help of two binary *m*-sequences of length 255, *x*, and *y*, respectively. The *x* sequence is constructed using the polynomial $1+X^2+X^3+X^4+X^8$. The *y* sequence is constructed using the polynomial $1+X^3+X^5+X^6+X^8$.
Before we define the Primary and Secondary code words, we define the set of orthogonal Gold codes.
Let $n_7 \ldots n_0$ be the binary representation of the scrambling code number *n* (decimal) with n_0 being the least significant bit. The *x* sequence depends on the chosen code number *n* and is denoted x_n in the sequel. Furthermore, let $x_n(i)$ and $y(i)$ denote the *i*:th symbol of the sequence x_n and *y*, respectively
The *m*-sequences x_n and *y* are constructed as:
Initial conditions:
$x_n(0)=n_0,\ x_n(1)=n_1,\ \ldots\ =x_n(6)=n_6,\ x_n(7)=n_7$
$y(0)=y(1)=\ \ldots\ =y(6)=y(7)=1$
Recursive definition of subsequent symbols:
$x_n(i+8)=x_n(i+4)+x_n(i+3)+x_n(i+2)+x_n(i)$ *modulo 2*, $i=0,\ldots,246$,
$y(i+8)=y(i+6)+y(i+5)+y(i+3)+y(i)$ *modulo 2*, $i=0,\ldots,246$.
The definition of the *n*:th SCH code word follows (the left most index correspond to the chip transmitted first in each slot):
$C_{SCH,n} = < 0,\ x_n(0)+y(0),\ x_n(1)+y(1),\ \ldots, x_n(254)+y(254) >$,
All sums of symbols are taken modulo 2.
Note that the code words always start with a constant '0'. symbol.
Before modulation and transmission these binary code words are converted to real valued sequences by the transformation '0' -> '+1', '1' -> '-1'.
The Primary and Secondary code words are defined in terms of $C_{SCH,n}$ and the definition of C_p and $\{C_1,\ldots,C_{17}\}$ now follows as:
$C_p = C_{SCH,0}$
and
$C_i = C_{SCH,i}$, $i=1,\ldots,17$

4.3.3 Modulation

4.3.3.1 Modulating chip rate

The modulating chip rate is 4.096 Mcps. This basic chip rate can be extended to 8.192 or 16.384 Mcps.

4.3.3.2 Pulse shaping

The pulse-shaping filters are root raised cosine (RRC) with roll-off α=0.22 in the frequency domain.

4.3.3.3 Modulation

QPSK modulation is used.

---

5 Radio transmission and reception (FDD)

<Editor's note: Input needed on many of the topics in this section.>

5.1 General

The information presented in this section is based on a chip rate of 4.096 Mcps. Appropriate adjustments should be made for higher chip rate options.

5.2 Frequency bands and channel arrangement

5.2.1 Proposed frequency bands for operation

UTRA/FDD is designed to operate in the following paired band:

1920 – 1980 MHz Mobile station transmit Base station receive	2110 – 2170 MHz Mobile station receive Base station transmit

Table 3. Proposed frequency band for UTRA/FDD

Deployment in other frequency bands is not precluded.

5.5.2 Carrier spacing

The nominal channel spacing is 5 MHz, but this can be adjusted to optimise performance in particular deployment scenarios. The channel raster is 200 kHz, which means that the carrier frequency must be a multiple of 200 kHz.

5.2.3 TX – RX frequency separation

The minimum transmit to receive separation is 130 MHz when operating in the paired band defined in Table 3.

5.2.4 Variable duplex distance

UTRA/FDD should support a variable duplex distance, i.e. $D_{duplexer} = F_{down} - F_{up}$ is not necessary a constant but is, in general, allowed to vary within certain limits. The specific limits for the duplex distance applicable for different frequency bands and terminal classes are yet to be determined.

5.3 Service classes

5.3.1 Terminal service classes

A number of different service classes will be used to define the data rate and code allocation for a UTRA/FDD terminal. Possible types of service class profiles are 144 kbps, 384 kbps and 2048 kbps.

5.4 Transmitter characteristics

The output power is given in terms of power level at the antenna connector of the equipment. For equipment with integral antenna only, a reference antenna with a gain of 0 dBi is assumed.

5.4.1 Mobile station output power

The mobile station output power profile would be used to define a range of terminal output powers for use in different system scenarios. The power class would be based on the mobile station's peak power for example 30 dBm. For mobile station using directive antennas for transmission, a class dependent limit will be placed on the maximum EIRP (Equivalent Isotropic Radiated Power).

5.4.2 Base station output power

The base station output power profile would be used to cater for different system scenarios. The power class would be based on the peak power specified for the base stations.

5.4.3 Output power dynamics

The transmitter uses fast closed-loop Carrier/Interference based power control and slow quality-based power control on both the uplink and downlink.

	Uplink (UL)	Downlink (DL)
Power control steps	Variable 0.25-1.5 dB	Variable 0.25-1.5 dB
Minimum transmit power	-50 dBm	[ ] dBm
Power control cycles per second	1.6 kHz	1.6 kHz
Power control dynamic	80 dB	30 dB

Table 4. Output power dynamics for UL and DL

5.4.4 Output RF spectrum emissions

5.4.4.1 Out of band emissions

The assumed spectrum mask has been derived from simulations on a real wide band amplifier as shown in Figure 27 below. These emission levels will be dependent on the power class and code allocation of the mobile and base station.

Title: cdma_masks_m.eps
Creator: MATLAB, The Mathworks, Inc.
CreationDate: 09/25/97 13:32:55

Figure 27. Assumed spectrum masks.

5.4.4.2 Spurious emissions

The limits for spurious emissions at frequencies greater than ± 250% of the necessary bandwidth would be based on the applicable tables from ITU-R Recommendation SM.329. Further guidance would be taken from the ERC recommendation that is currently under progress.

5.4.5 Adjacent channel protection (ACP)

Adjacent channel protection (ACP) is the ratio of the transmitted power and the power measured after a receiver filter in the adjacent channel.
The ACP envisaged for 5 MHz channel spacing is in the order of 35 dB to 40 dB. The possibility is being considered of dynamically relaxing the ACP requirements for mobile stations under conditions when this would not lead to significant interference (with respect to other systems or UMTS operators). This would be carried out under network control, primarily to facilitate reduction in MS power consumption.

5.4.6 Occupied bandwidth

The channel bandwidth is less than 5 MHz based on a chip rate of 4.096 Mcps.

5.4.7 Frequency stability

The frequency stability for the mobile and base station is indicated in Table 5.

Mobile station	Base station
3 PPM (unlocked), 0.1 PPM (locked)	0.05 PPM

Table 5. Mobile and base station frequency stability.

5.5 Receiver characteristics

A Rake receiver or any other suitable receiver structure using coherent reception in both channel impulse response estimation, and code tracking procedures is assumed.

5.5.1 Diversity characteristics

Three forms of diversity are available in UTRA / FDD:

Time diversity	Channel coding and interleaving in both up link and down link.
Multi-path diversity	Rake receiver or other suitable receiver structure with maximum combining. Additional processing elements can increase the delay-spread performance due to increased capture of signal energy.

Space diversity	Antenna diversity with maximum ratio combing in the base station and optionally in the mobile stations. Possibility for downlink transmit diversity in the base station.

Table 6. Diversity characteristics for UTRA/FDD.

5.5.2 Reference sensitivity level

The reference sensitivity for the following services; 8 kbps, 144 kbps, 384 kbps and 2048 kbps are specified in the link budget template for a number of test environments and multi-path channel classes.

5.5.3 BER noise floor level

The BER noise floor level for voice services is significantly less than 10^{-3} BER. The BER noise floor level for data services is significantly less than 10^{-6} BER.

5.5.4 Maximum tolerable delay spread

To maintain the voice and data service quality requirements the UTRA/FDD concept allows for a time dispersion spread suitable for the various propagation models specified in UMTS 30.03.

5.5.5 Maximum tolerable Doppler spread

The maximum tolerable Doppler spread is 1000 Hz, which at a 2 GHz carrier frequency corresponds to a maximum velocity of about 500 km/hr. Parameters determining system performance are not necessarily optimised for this value of Doppler spread.

6 Physical layer procedures (FDD)

6.1 General

6.2 Power control

6.2.1 Uplink power control

6.2.1.1 Closed loop power control

The uplink closed loop power control adjusts the mobile station transmit power in order to keep the received uplink Signal-to-Interference Ratio (SIR) at a given SIR target.
The base station should estimate the received uplink DPCCH power after RAKE combining of the connection to be power controlled. Simultaneously, the base station should estimate the total uplink received interference in the current frequency band and generate a SIR estimate SIR_{est}. The base station then generates TPC commands according to the following rule:

$SIR_{est} > SIR_{target,UL} \rightarrow$ TPC command = "down"

$SIR_{est} < SIR_{target,UL} \rightarrow$ TPC command = "up"

Upon the reception of a TPC command, the mobile station should adjust the transmit power of both the uplink DPCCH and the uplink DPDCH in the given direction with a step of Δ_{TPC} dB. The step size Δ_{TPC} is a parameter that may differ between different cells, in the region 0.25 – 1.5 dB.
In case of receiver diversity (e.g., space diversity) or softer handover at the base station, the TPC command should be generated after diversity combining.
In case of soft handover, the following procedure is considered:

- in the base stations a quality measurement is performed on the received signals; in case the quality measurement indicates a value below a given threshold, an increase command is sent to the mobile, otherwise a decrease command is transmitted; all the base stations in the active set send power control commands to the mobile;
- the mobile compares the commands received from different base stations and increases its power only if all the commands indicate an increase value (this means that all the receivers are below the threshold); in case one command indicates a decrease step (that is, at least one receiver is operating in good conditions), the mobile reduces its power; in case more than one decrease commands are received by the mobile, the mobile station should adjust the power with the largest step in the "down" direction ordered by the TPC commands received from each base station in the active set.
- the quality threshold for the base stations in the active set should be adjusted by the outer loop power control (to be implemented in the network node were soft handover combining is performed).

6.2.1.2 Outer loop (SIR target adjustment)

The outer loop adjusts the SIR target used by the closed-loop power control. The SIR target is independently adjusted for each connection based on the estimated quality of the connection. In addition, the power offset between the uplink DPDCH and uplink DPCCH may be adjusted. How the quality estimate is derived and how it affects the SIR target is decided by the radio-resource management, i.e. it is not a physical-layer issue.

6.2.1.3 Open-loop power control

Open-loop power control is used to adjust the transmit power of the physical Random-Access channel. Before the transmission of a Random-Access burst, the mobile station should measure the received power of the downlink Primary CCPCH over a sufficiently long time to remove effects of the non-reciprocal multi-path fading. From the power estimate and knowledge of the Primary CCPCH transmit power (broadcast on the BCCH) the downlink path-loss including shadow fading can be found. From this path loss estimate and knowledge of the uplink interference level and the required received SIR, the transmit power of the physical Random-Access channel can be determined. The uplink interference level as well as the required received SIR are broadcast on the BCCH.

6.2.2 Downlink power control

6.2.2.1 Closed loop power control

The downlink closed loop power control adjusts the base station transmit power in order to keep the received downlink SIR at a given SIR target.

The mobile station should estimate the received downlink DPCH power after RAKE combining of the connection to be power controlled. Simultaneously, the mobile station should estimate the total downlink received interference in the current frequency band. The mobile station then generates TPC commands according to the following rule:

$SIR_{est} > SIR_{target,DL} \rightarrow$ TPC command = "down"

$SIR_{est} < SIR_{target,DL} \rightarrow$ TPC command = "up"

Upon the reception of a TPC command, the base station should adjust the transmit power in the given direction with a step of Δ_{TPC} dB. The step size Δ_{TPC} is a parameter that may differ between different cells, in the range 0.25 – 1.5 dB.

In case of receiver diversity (e.g., space diversity) at the mobile station, the TPC command should be generated after diversity combining.

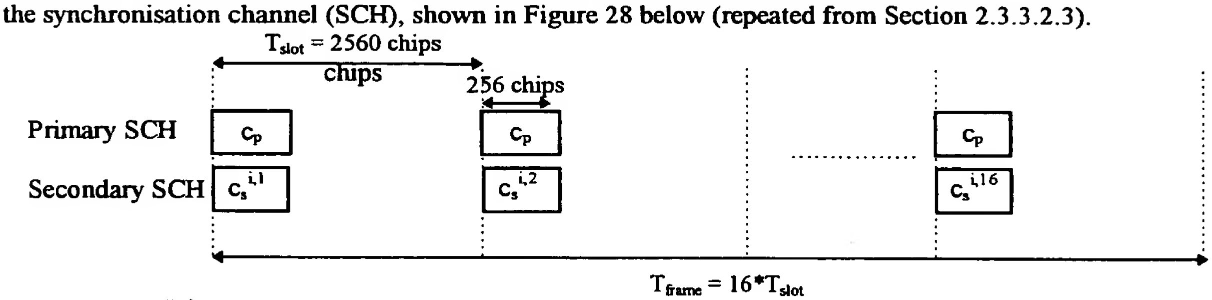
6.2.2.2 Outer loop (SIR target adjustment)

The outer loop adjusts the SIR target used by the closed-loop power control. The SIR target is independently adjusted for each connection based on the estimated quality of the connection. In addition, the power offset between the downlink DPDCH and DPCCH may be adjusted. How the quality estimate is derived and how it affects the SIR target is decided by the radio-resource management, i.e. it is not a physical-layer issue.

6.3 Cell search

6.3.1 Initial cell search

During the initial cell search, the mobile station searches for the base station to which it has the lowest path loss. It then determines the downlink scrambling code and frame synchronisation of that base station. The initial cell search uses the synchronisation channel (SCH), shown in Figure 28 below (repeated from Section 2.3.3.2.3).



c_p : Primary Synchronization Code

$c_s^{i,k}$: One of 17 possible Secondary Synchronization Codes

$(c_s^{i,1}, c_s^{i,2}, \ldots, c_s^{i,16})$ encode cell specific long scrambling code group i

Figure 28. Structure of synchronisation channel (SCH).

This initial cell search is carried out in three steps:

Step 1: Slot synchronisation

During the first step of the initial cell search procedure the mobile station uses the primary SCH to acquire slot synchronisation to the strongest base station. This is done with a single matched filter (or any similar device) matched to the primary synchronisation code c_p which is common to all base stations. The output of the matched filter will have peaks for each ray of each base station within range of the mobile station, see Figure 29. Detecting the position of the strongest peak gives the timing of the strongest base station modulo the slot length. For better reliability, the matched-filter output should be non-coherently accumulated over a number of slots.

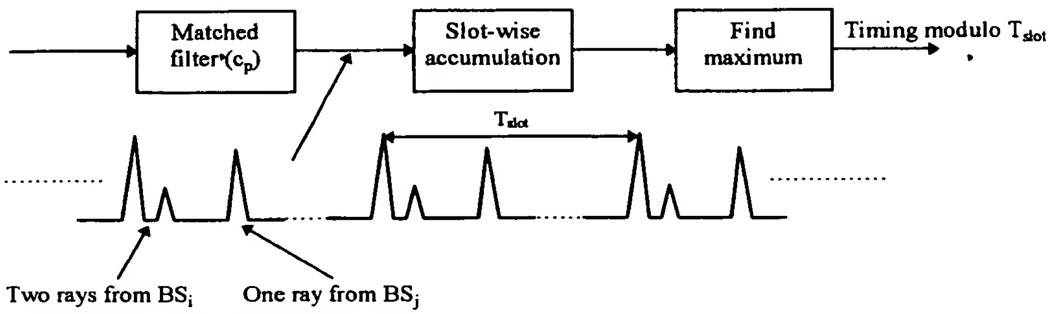


Figure 29. Matched-filter search for primary synchronisation code to slot synchronisation (timing modulo the slot length).

Step 2: Frame synchronisation and code-group identification

During the second step of the initial cell search procedure, the mobile station uses the secondary SCH to find frame synchronisation and identify the code group of the base station found in the first step. This is done by correlating the received signal at the positions of the Secondary Synchronisation Code with all possible (17) Secondary Synchronisation Codes. Note that the position of the Secondary Synchronisation Code is known after the first step. The outputs of all the 17 correlators for 16 consecutive secondary SCH locations are used to form the decision variables. The decision variables are obtained by *non-coherently* summing the correlator outputs corresponding to each 16 length sequence out of the 32 possible sequences and its 16 cyclic shifts giving a total of 512 decision variables. Note that the cyclic shifts of the sequences are unique (see Section 2.3.3.2.2). Thus, by identifying the sequence/shift pair that gives the maximum correlation value, the code group as well as the frame synchronisation is determined.

Step 3: Scrambling-code identification

During the third and last step of the initial cell-search procedure, the mobile station determines the exact scrambling code used by the found base station. The scrambling code is identified through symbol-by-symbol correlation over the Primary CCPCH with all scrambling codes within the code group identified in the second step. Note that, from step 2, the frame boundary and consequently the start of the scrambling code is known. Correlation must be carried out symbol-wise, due to the unknown data of the primary CCPCH. Also, in order to reduce the probability of wrong/false acquisition, due to combat background noise/interference, averaging the correlator outputs over a sequence of symbols (diversity) might be required before using the outputs to determine the exact scrambling code.
After the scrambling code has been identified, the Primary CCPCH can be detected, super-frame synchronisation can be acquired and the system- and cell specific BCCH information can be read.

6.3.2 Idle mode cell search

When in idle mode, the mobile station continuously searches for new base stations on the current and other carrier frequencies. The cell search is done in basically the same way as the initial cell search. The main difference compared to the initial cell search is that an idle mobile station has received a priority list from the network. This priority list describes in which order the downlink scrambling codes should be searched for and does thus significantly reduce the time and effort needed for the scrambling-code search (step 3). Also the complexity in the second step may be reduced if the priority list only includes scrambling codes belonging to a subset of the total set of code groups. The priority list is continuously updated to reflect the changing neighbourhood of a moving mobile station.

6.3.3 Active mode cell search

When in active mode, the mobile station continuously searches for new base stations on the current carrier frequency. This cell search is carried out in basically the same way as the idle mode cell search. The mobile station may also search for new base stations on other carrier frequencies using the slotted mode, see Section 6.5.2.1.1.

6.4 Random access

The procedure of a random access request is:

1. The mobile station acquires synchronisation to a base station
2. The mobile station reads the BCCH to get information about:
   - 2.1 The preamble spreading code(s) /message scrambling code(s) used in the cell
   - 2.2 The available signatures
   - 2.3 The available access slots
   - 2.4 The available spreading factors for the message part
   - 2.5 The interference level at the base station
   - 2.6 The primary CCPCH transmit power level
3. The mobile station selects a preamble spreading code/message scrambling code
4. The mobile station selects a spreading factor for the message part.
5. The mobile station estimates the downlink path loss (by using information about the transmitted and received power level of the primary CCPCH), and determines the required uplink transmit power (by using information about the interference level at the base station).
6. The mobile station randomly selects an access slot and signature from the available access slots and signatures.
7. The mobile station transmits its random access burst.
8. The mobile station waits for an acknowledgement from the base station. If no acknowledgement is received within a predefined time-out period, the mobile station starts again from step 5.

A typical implementation of the base-station random-access receiver for a given preamble code and preamble sequence is illustrated in Figure 30. The received signal is fed to a matched filter, matched to the preamble code. The output of the matched filter is then correlated with the preamble sequence. The output of the preamble correlator will have peaks corresponding to the timing of any received Random-Access burst using the specific preamble code and preamble sequence. The estimated timing can then be used in a ordinary RAKE combiner for the reception of the data part of the Random-Access burst.

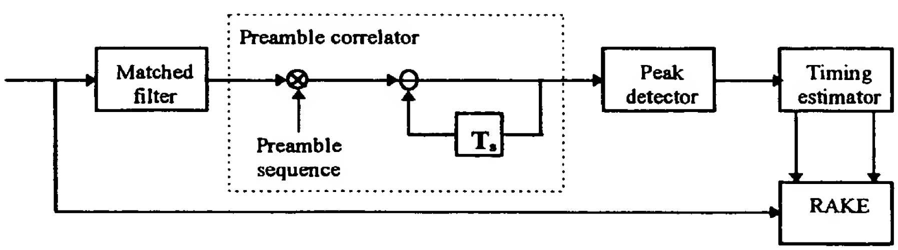


Figure 30. Base-station Random-Access receiver.

Upon reception of the Random-Access burst, the base station responds with an Access Grant message on the FACH. In case the Random Access request is for a dedicated channel (circuit-switched or packet) and the request is granted, the Access Grant message includes a pointer to the dedicated physical channel(s) to use. As soon as the mobile station has moved to the dedicated channel, closed-loop power control is activated.

6.5 Handover

6.5.1 Intra-frequency handover

Soft handover

When in active mode, the mobile station continuously searches for new base stations on the current carrier frequency. During the search, the mobile station monitors the received signal level from neighbouring base stations, compares them to a set of thresholds, and reports them accordingly back to the base station. Based on this information the network orders the mobile station to add or remove base station links from its *active set*. The *active set* is defined as the set of base station from which the same user information is sent, simultaneously demodulated and coherently combined, i.e. the set of base stations involved in the soft handover.
From the cell-search procedure, the mobile station knows the frame offset of the Primary CCPCH of potential soft-handover candidates relative to that of the source base station(s) (the base stations currently within the active set).

When a soft handover is to take place, this offset together with the frame offset between the downlink DPCH and the Primary CCPCH of the source base station, is used to calculate the required frame offset between the downlink DPCH and the Primary CCPCH of the destination base station (the base station to be added to the active set). This offset is chosen so that the frame offset between the downlink DPCH of the source and destination base stations at the mobile-station receiver is minimised. Note that the offset between the downlink DPCH and Primary CCPCH can only be adjusted in steps of one downlink DPCH symbol in order to preserve downlink orthogonality. See also Section 2.5.

Softer handover

Softer handover is the special case of a soft handover between sectors/cells belonging to the same base station site. Conceptually, a softer handover is initiated and executed in the same way as an ordinary soft handover. The main differences are on the implementation level within the network. For softer handover, it is e.g. more feasible to do uplink maximum-ratio combining instead of selection combining as the combining is done on the BTS level rather than on the BSC level.

6.5.1.1 Measurements

6.5.1.2 Handover execution procedure

6.5.2 Inter-frequency handover

In UTRA/FDD the vast majority of handovers are within one carrier frequency, i.e. intra-frequency handover. Inter-frequency handover may typically occur in the following situations:

- Handover between cells to which different number of carriers have been allocated, e.g. due to different capacity requirements (hot-spot scenarios).
- Handover between cells of different overlapping orthogonal cell layers using different carrier frequencies
- Handover between different operators/systems using different carrier frequencies including handover to GSM.

A key requirement for the support of seamless inter-frequency handover is the possibility for the mobile station to carry out cell search on a carrier frequency different from the current one, without affecting the ordinary data flow. UTRA/FDD supports inter-frequency cell search in two different ways, a dual-receiver approach and a slotted-downlink-transmission approach.

6.5.2.1 Measurements

6.5.2.1.1 Slotted mode

With slotted downlink transmission, it is possible for a single-receiver mobile station to carry out measurements on other frequencies without affecting the ordinary data flow. The principle of slotted downlink transmission is illustrated in Figure 31.

When in slotted mode, the information normally transmitted during a 10 ms frame is compressed in time. This can be achieved by :

- code puncturing, for lower compression factors,
- changing the FEC rate, for higher compression factors.

Note that the idle slot is created without any loss of data as the number of information bits per frame is kept constant, while the processing gain is reduced by increasing the coding rate. As illustrated in Figure 31, the instantaneous transmit power is increased in the slotted frame in order to keep the quality (BER, FER, etc.) unaffected by the reduced processing gain.

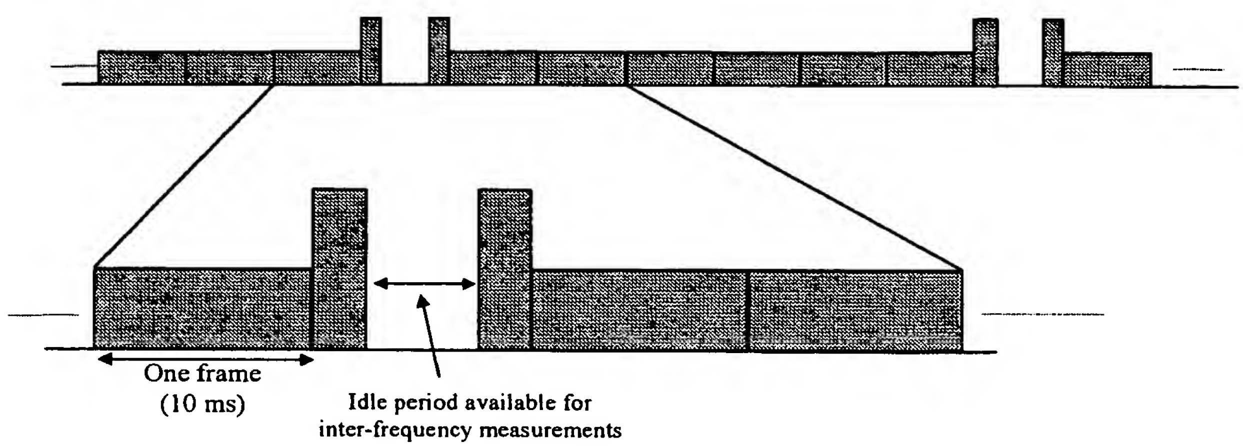


Figure 31. Downlink slotted transmission.

Although Figure 31 shows slotted transmission with a mid-frame idle-period, there are in general three types of possible slotted transmission mechanisms, as illustrated in Figure 32.

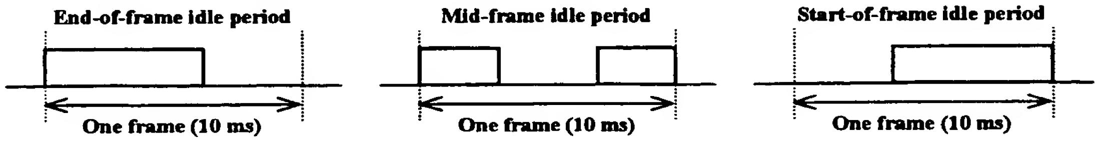


Figure 32. Possible idle period positions.

The default position is the mid-frame idle period. The start-of-frame and end-of-frame idle are supported in order to be able to create an even longer double-frame idle period, as illustrated in Figure 32.

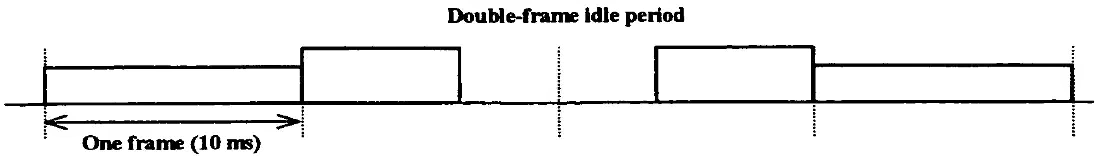


Figure 33. Double-frame idle period.

When in slotted mode, slotted frames can occur periodically, as illustrated in Figure 31, or requested on demand. The rate of and type of slotted frames is variable and depends on the environment and the measurement requirements.
For UTRA-to-GSM inter-frequency handover considerations, see section 14.2.
For services that allows for a larger delay, e.g. data services with interleaving over several frames, multiple frames can be compressed together in order to create a short measurement slot. As an example, for a 2 Mbps service, with interleaving of 5 frames (50 ms), a 5 ms idle slot can be created by puncturing only 10% of 5 frames, as illustrated in Figure 34.

Figure 34. Multi-frame compressed mode for long-delay services.

6.5.2.1.2 Dual Receiver Approach

Mobile terminals equipped with receiver antenna diversity can switch one diversity branch periodically to another frequency for measurement purposes. This results in a slight loss in diversity capability. Another option is to have a separate receiver, dedicated for inter-frequency measurement purposes.

6.5.2.2 Handover execution procedure

6.6 Idle mode tasks

6.6.1 Paging control

6.6.1.1 BS operation

The MSs shall be grouped by a specified method, and paged by each group. At the BS, the corresponding group number is designated, together with the terminating information that includes the MS ID number that had a terminating call. The BS shall transmit the terminating information with the MUI part of PCH of the designated group number.

For the PCH of the group which does not have terminating information:

- The BS shall transmit the two PI parts (PI1 and PI2) in the PCH as "all 0".
- The MUI part shall not be transmitted.

For the PCH of the group which have terminating information:

- The BS shall transmit the two PI parts (PI1 and PI2) in the PCH as "all 1".
- The MUI part shall be transmitted within the same PCH.

6.6.1.2 MS operation

The MS shall normally receive only the PI1. The (soft decision) majority decision process of PI1 shall be performed.
- Result of the process equal to "1" with high reliability:
  The MUI part of the same PCH shall be received.

- Result of the process equal to "0" with high reliability:
  Reception shall be kept OFF until the end of the current superframe.
- Result of the process with low reliability:
  PI2 within the same PCH shall be received.
  The majority decision process of PI2 shall be performed.
  - Result of the process equal to "1" with high reliability:
    The MUI part of the same PCH shall be received.
  - Result of the process equal to "0" with high reliability:
    Reception shall be kept OFF until the end of the current superframe.
  - Result of the process with low reliability
    The MUI shall be received.

When the MUI part is received, the existence of terminating calls for the MS shall be judged based on the terminating information included in the MUI part.

7 Additional features and options (FDD)

7.1 Adaptive antennas

Adaptive antennas are recognised as a way to enhance capacity and coverage of the system. Solutions employing adaptive antennas are already supported in the UTRA/FDD concept through the use of connection-dedicated pilot bits on both uplink and downlink.

7.2 Multi-user detection

UTRA/FDD is designed to work without requiring joint detection of multiple user signals. However, the potential capacity gains of such receivers in a UTRA/FDD system have been recognised and taken into account in the design of the concept. In the uplink the possibility to use only short codes facilitates more advanced receiver structures with reasonable complexity.

7.3 Downlink transmit diversity

Transmitter diversity in the downlink provides a means to significantly improve capacity and coverage of UTRA/FDD, without the requirement for a second receiver chain in the mobile station that receiver diversity would entail. However, a typical transmit diversity technique, such as delay transmit diversity, has two main drawbacks: self-interference at locations with good SINR; and the requirement for additional Rake fingers in the mobile receiver. In order to overcome these drawbacks, diversity schemes have been proposed for UTRA/FDD, that maintain the orthogonality between diverse downlink transmit antennas, whilst offering significant advantages in the downlink performance. Simulation results for the proposed techniques have shown a gain of up to 7 dB (compared with the non-diversity case) for slow speed mobiles in a single path fading environment. In the proposed schemes, the orthogonality between antennas, is maintained using either code, or time division.

7.3.1 Code division transmit diversity

7.3.1.1 Orthogonal Transmit Diversity

Orthogonal Transmit Diversity (OTD) utilises code division transmission diversity. The implementation of OTD is as follows. Coded bits are split into two data streams and transmitted via two separate antennas. Different orthogonal channelisation codes are used per antenna for spreading. This maintains the orthogonality between the two output streams, and hence self-interference is eliminated in flat fading. Note that by splitting the coded data into two separate data streams, the effective number of channelisation codes per user is the same as the case without OTD.
The above structure is highly flexible, it may be easily extended to more antennas (4, 8, etc.)
OTD may be an optional feature that can be turned on only if needed. In addition, it is possible to support a mixture of mobiles with and without OTD capability.
The additional required processing at the mobile station is small. Figure 35 illustrates Rake finger processing with OTD. It is important to note that the Pilot signal is also split and transmitted on both antennas which allows coherent detection of the signals received from both antenna. The data is processed using a Rake finger with parallel processing capability. Both transmitted signal streams are received simultaneously at the same delay (for a given multipath ray), hence no additional buffering and skewing of data is necessary. This significantly reduces the hardware complexity/cost associated with OTD implementation.

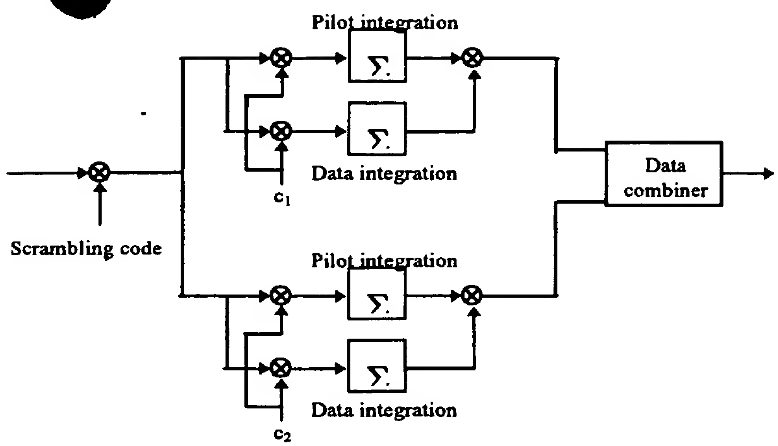


Figure 35. Rake finger processing with OTD.

In the base station transmitter, the baseband processing (i.e. data splitting and separate spreaders) required for OTD already exists with multicode transmission in the downlink. From the OTD viewpoint, it is advantageous to employ multicode transmission for all data rates, and it is also recommended to match the number of codes assigned to the user with the number of transmit antennas.

7.3.2 Time division transmit diversity

Two schemes have been put forward utilising time division transmission diversity for downlink UTRA/FDD mode operation. The basic Base Station Transmitter block diagram for Time Transmission Diversity is shown in Figure 36. In time division transmission diversity the signal is switched between antennas in one of two ways. Either, the signal is switched according to a pattern decided by the base station, or it is switched depending on signalling received from the mobile station.

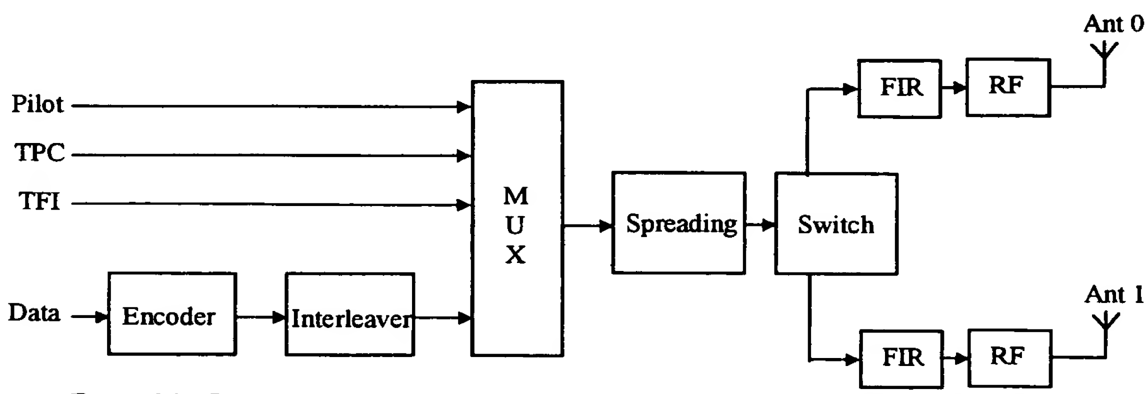


Figure 36. Base station transmitter block diagram for time division transmission diversity.

7.3.2.1 Time Switched Transmission Diversity

Time switched transmission diversity (TSTD) is implemented using the block diagram exactly as shown in Figure 36. TSTD does not assume any change to the UTRA/FDD physical layer channel structure other than switching at the filter input. There is no change to the channel coding, rate matching, interleaving and spreading within the UTRA/FDD physical layer description.

TSTD is used for the transmission of downlink Dedicated Physical Channels (DPCHs). All other downlink channels, i.e. the Common Control Physical Channels (CCPCHs) and the Synchronisation Channel (SCH), are transmitted from a single antenna, without diversity. TSTD is implemented by transmitting consecutive slots of the downlink DPCHs through two separate antennas. After scrambling, the spread time slots are switched consecutively to each antenna (i.e. the baseband signal is switched before modulation is applied, between transmitter antennas, at a rate of once every 0.625 ms).

The BCCH informs all mobile stations of the corresponding base station's capability for TSTD. The DPDCH and the DPCCH in the same slot for a given mobile station, are then transmitted from one of the antennas. The next slot of the DPCH is transmitted from the other antenna. The DPCHs of other users operating in TSTD mode, may have different switching patterns in order to reduce the peak transmit power and peak to average power ratio in each power amplifier.

The spread time slots are transmitted to each antenna sequentially as shown in Figure 37.

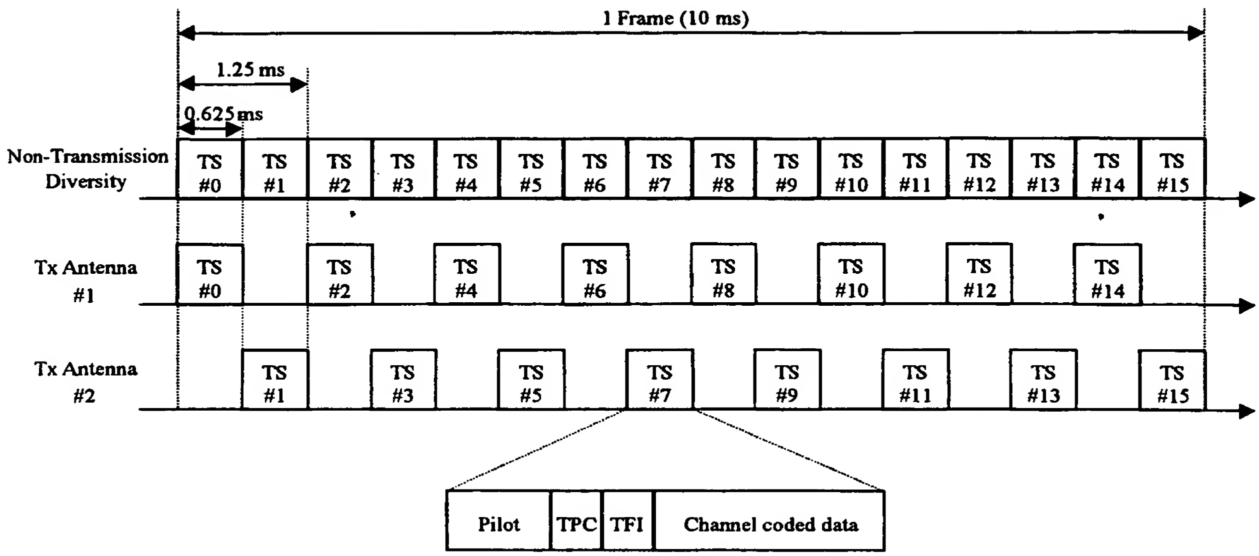


Figure 37. Switching pattern for Dedicated Physical Channels in TSTD.

7.3.2.2 Selection Transmit Diversity

Selection Transmit Diversity (STD) with fast closed loop control may be used to provide transmit diversity. For STD, the structure of the Base Station Transmitter is as shown in Figure 38. The implementation of STD is as follows. In the case of no soft handover, the base station antenna is dynamically selected, based on a fast transmit antenna selection (AS) control signal, transmitted by the mobile station (similar to fast PC loop). The value of the AS bit is determined, based on measurements on the antenna specific Primary CCPCH channel. The control loop speed is 400 Hz (note: the exact AS control loop speed is for further study). In order to guarantee that the mobile station is decoding the right downlink signal, the pilot symbols of the antennas are selected to be orthogonal with each other.

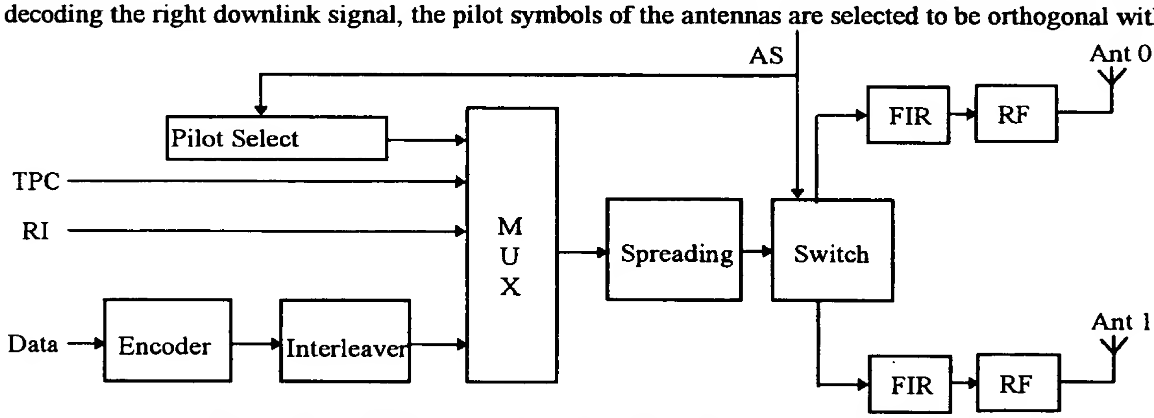


Figure 38. Selective Transmit Diversity: Base station transmitter block diagram.

7.4 Locationing function support

The wideband nature of the UTRA/FDD facilitates the high resolution in position location as the resolution achievable is directly proportional to the channel symbol rate, in this case chip rate. The duration of one chip corresponds to approximately 73 meters in propagation distance and if the delay estimation operates on the accuracy of samples/chip then the achievable maximum accuracy is approximately 18 meters with the 4.096 Mcps chip rate. Naturally there are then other inaccuracies that will cause degradation to the positioning but 18 meters can be considered as kind of lower bound on the positioning performance. With higher sampling rate or chip rate the bound is then naturally even lower.
With the UTRA/FDD concept the position location has been discussed in several ETSI/SMG2 input documents.. One example solution to use is the proposed power up function (PUF) which in the need for a MS to be heard by several base stations will increase the transmission power over short interval. Other aspects of the position mechanism are how the issue of actual measurement is done and whether that is based on loop around time or on Time Difference Of Arrival (TDOA) or other measures.

8 Transport and physical channels (TDD)

9 Multiplexing, channel coding and interleaving (TDD)

10 Spreading and modulation (TDD)

11 Radio transmission and reception (TDD)

12 Physical layer procedures (TDD)

13 Additional features and options (TDD)

14 Interoperability

14.1 UTRA/FDD - UTRA/TDD handover

For terminals with both FDD and TDD capability the handover between the UTRA modes can be used. Both modes use the same 10 ms frame length and can perform measurements on each other. The UTRA FDD mode can use the slotted mode or other measurement ways described in section 6.5.2.1 to perform measurements on the UTRA TDD mode. The UTRA FDD mode must search first the downlink activity part(s) in the 10 ms frame. As the UTRA TDD cells within the area are frame synchronised, the downlink/uplink timing obtained for a single TDD cell is also valid for other cells belonging to the same network in the same area.

For the UTRA TDD mode, measurement time can be obtained between the activity periods (between uplink/downlink transmission) to facilitate sufficient measurement frequency from UTRA FDD cells.

In the FDD mode, the mobile is continuously transmitting and receiving information. In order to perform a handover to the TDD mode, it should be able to make measurements on TDD carriers. However, the spectral separation between FDD carriers and TDD carriers may not be sufficient in some cases to be able to implement a filter to protect the TDD receiver making the measurements. Therefore, the mobile might need to interrupt FDD transmission in order to perform measurements in the TDD band. This can be implemented through a slotted mode in the uplink direction similar to the one defined for the downlink transmission.

For both modes it is expected that the UTRA base station is able to indicate the channel numbers used for the FDD and TDD cells in the area as well as the base station spreading/scrambling codes used. This does not cover the unlicensed TDD use where handovers are not likely to happen as the networks are not likely to be inter-connected.

14.2 UTRA - GSM handover

The handover between UTRA and GSM system offering world-wide coverage already today has been one of the main design criteria taken into account in the UTRA frame timing definition. The GSM compatible multiframe structure, with the superframe being multiple of 120 ms, allows similar timing for inter-system measurements as in the GSM system itself. The compatibility in timing is important, that when operating in UTRA mode, a multimode terminal is able to catch the desired information from the synchronisation bursts in the synchronisation frame on a GSM carrier with the aid of the frequency correction burst. This way the relative timing between a GSM and UTRA carriers is maintained similar to the timing between two asynchronous GSM carriers.

14.2.1 UTRA/FDD to GSM handover

UTRA/FDD-GSM dual mode terminals can be implemented without simultaneous use of two receiver chains. Although the frame length is different from GSM frame length, the GSM traffic channel and UTRA FDD channels use similar 120 ms multiframe structure. Similar timing can be naturally done with UTRA TDD mode as well.

A UTRA terminal can do the measurements either by requesting the measurement intervals in a form of slotted mode where there are breaks in the downlink transmission or then it can perform the measurements independently with a suitable measurement pattern. Independent measurements do not use slotted mode, but use dual receiver approach, where the GSM receiver branch can operate independently of the UTRA FDD receiver branch.

For smooth inter-operation between the systems, information needs to be exchanged between the systems, in order to allow UTRA base station to notify the terminal of the existing GSM frequencies in the area. Further more integrated

operation is needed for the actual handover where the current service is maintained, taking naturally into account the lower data rate capabilities in GSM when compared to UMTS maximum data rates reaching all the way to 2 Mbps.

Measurements of GSM using slotted mode

6 ms idle periods (similar to that of GSM) can be created by using double-frame idle periods, as described in section 6.5.2.1.1. Therefore, it is possible to capture the GSM FCCH and SCH in the same way as in GSM-to-GSM handover. The GSM Frequency Correction Channel (FCCH) and GSM Synchronisation Channel (SCH) use one slot out of the eight GSM slots in the indicated frames with the FCCH frame with one time slot for FCCH always preceding the SCH frame with one time slot for SCH. The principle is indicated in Figure 39.

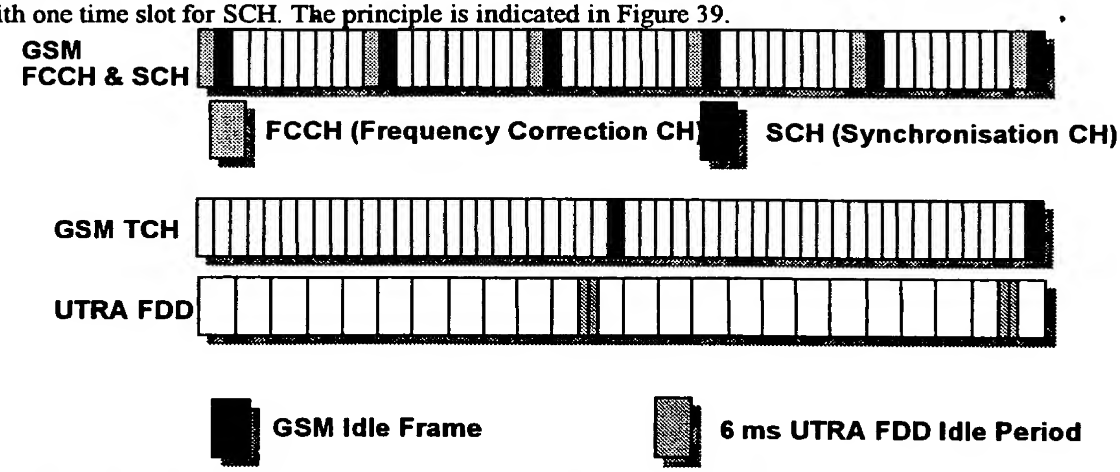


Figure 39. Example of GSM measurement timing relation between UTRA/FDD and GSM frame structures.

Alternatively, several shorter mid-frame idle periods (as described in section 6.5.2.1.1) with a certain spacing and every GSM superframe, can be used to capture the GSM FCCH and SCH. For instance, two 3 ms idle periods every 120 ms, offset from each other by 30 ms, as illustrated in Figure 40.

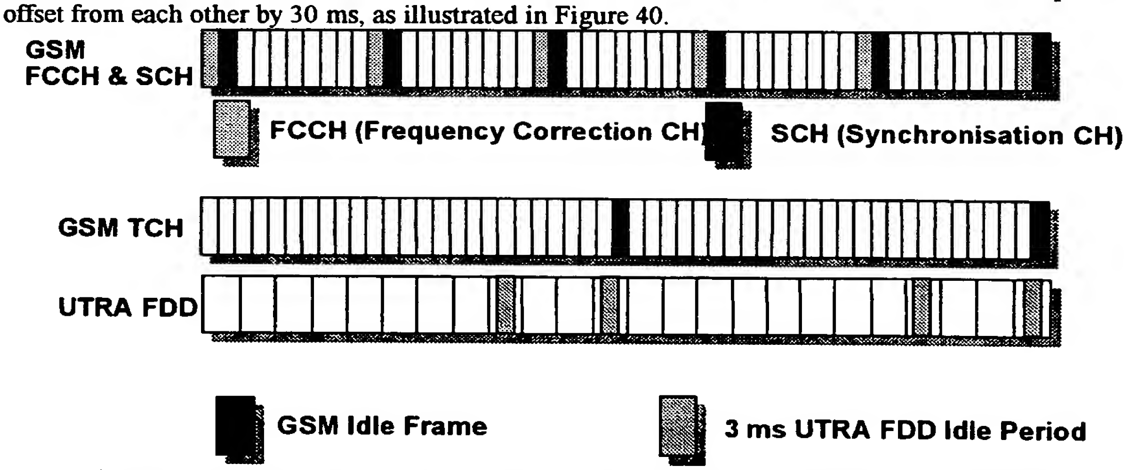


Figure 40. Another example of measurement timing relation between UTRA/FDD and GSM frame structures.

For the power measurements of GSM carriers, additional slotted frames will be used for single receiver FDD/GSM mobiles. Requirements concerning the number of power measurements per slotted frame are for further study.

14.2.2 GSM to UTRA/FDD handover

The GSM system is likewise expected to be able to indicate also the UTRA FDD base station scrambling codes in the area to make the cell identification simpler and after that the existing measurement practices in GSM, between the slots or during idle slots, can be used for measuring the UTRA FDD mode when operating in GSM mode.

As the UTRA FDD does not rely on any superframe structure as with GSM to find out synchronisation, the terminal operating in GSM mode is able to obtain UTRA FDD BS frame synchronisation once the UTRA FDD base station scrambling code timing is acquired. The BS scrambling code has 10 ms period and is synchronised to UTRA FDD common channels in the frame timing.

15 System scenarios

During the UTRA standards development, the physical layer parameters will be decided using system scenarios reflecting the environments that UTRA will be designed to operate in. It is anticipated that these scenarios will enable guard band recommendations to be made.

This section discusses system scenarios for UTRA operation primarily with respect to the radio transmission and reception. To develop the UTRA standard, all the relevant scenarios need to be considered for the various aspects of operation and the most critical cases identified. The process may then be iterated to arrive at final parameters that meet both service and implementation requirements.

Each scenario has three sections:

a) lists the system constraints such as the separation of the MS and BTS, coupling loss
b) lists those aspects that are affected by the constraints
c) lists the inputs required to examine the implications of the scenarios

The following scenarios will be discussed for FDD and TDD modes (further scenarios will be added as and when identified):

1) Single MS, single BTS
2) Multiple MS and BTS where operation of BTS's is coordinated
3) Multiple MS and BTS where operation of BTS's is uncoordinated
4) Colocated MS
5) Colocated BTS
6) Colocation with other systems

<Editor's note: Contributions are invited>

History

Document history		
v0.1	1998-04-24	Document created based on the documents Tdoc SMG2 UMTS-L1 36/98 and Tdoc SMG 905/97. (Tdoc SMG2 UMTS-L1 56/98)
v0.2	1998-05-20	Updated with additions and modifications agreed upon at the UMTS-L1 meeting in Bocholt, May 18-20. (Tdoc SMG2 UMTS-L1 161/98)
v0.2.1	1998-05-26	Many editorial changes. Also tried to reflect the decisions in Bocholt to better extent, following comments from various persons. Section 3 still not in line with discussion in Bocholt. (Tdoc SMG2 219/98)
v0.3	1998-05-29	New sections 3 and 5, plus some editorial changes. (Tdoc SMG2 UMTS-L1 163/98, Tdoc SMG2 258/98)
v0.3.1	1998-06-10	Editorial changes only, provided to UMTS-L1 meeting in Turin. (Tdoc SMG2 UMTS-L1 176/98)
v0.4	1998-06-24	Added text according to the decisions at the UMTS-L1 meeting in Turin. (Tdoc SMG2 UMTS-L1 221/98)

Editor for UMTS physical layer procedures, FDD parts, is:

Fredrik Ovesjö
Ericsson Radio Systems AB

Tel: +46 8 404 56 74
Fax: + 46 8 585 314 80
Email: Fredrik.Ovesjo@era-t.ericsson.se

This document is written in Microsoft Word 97.